B 942485

DEC 22 1961

ИЗМЕРИТЕЛЬНАЯ ТЕХНИКА

Number 6, June, 1961
Translation Published December, 1961

THE LIBRARY OF CONGRESS
SERIAL RECORD
JAN 15 1962
Copy

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Measurement Techniques

(The Soviet Journal *Izmeritel'naya Tekhnika* in English Translation)

■ This translation of a Soviet journal on instrumentation is published as a service to American science and industry. It is sponsored by the Instrument Society of America under a grant in aid from the National Science Foundation with additional assistance from the National Bureau of Standards.

SOVIET INSTRUMENTATION AND CONTROL TRANSLATION SERIES

Instrument Society of America

Philip A. Sprague
President
Dr. Ralph H. Tripp
Past President
Nathan Cohn
President-elect-Secretary
Henry J. Noebels
Dept. Vice President
Dr. Benjamin W. Thomas
Dept. Vice President-elect
E. A. Adler
Dept. Vice President
Francis S. Hoag
Dept. Vice President
John J. McDonald
Dept. Vice President
John R. Mahoney
Dept. Vice President-elect
John C. Koch
Treasurer
Alonzo B. Parsons
Dist. I Vice President
H. Kirk Fallin
Dist. II Vice President
Harold J. Bowman
Dist. III Vice President
Fred R. Gilmer
Dist. IV Vice President
Charles H. Callier
Dist. V Vice President
Otto J. Lessa
Dist. VI Vice President
J. Howard Park, III
Dist. VII Vice President
C. Roy Horton
Dist. VIII Vice President
Max Curtis
Dist. IX Vice President
Kenneth S. Vriesen
Dist. X Vice President
Allan E. Lee
Dist. XI Vice President

International Headquarters

William H. Kushnick
Executive Director
Charles W. Covey
Editor, ISA Journal
Herbert S. Kindler
Director, Tech. & Educ. Services

ISA Publications Committee

Charles O. Badgett, *Chairman*

Jere E. Brophy	George A. Larsen	Joshua Stern
Dr. Enoch J. Durbin	Thomas G. MacAnespie	Frank S. Swaney
Prof. Richard W. Jones	John E. Read	Richard A. Terry

Translations Advisory Board of the Publications Committee

Jere E. Brophy, *Chairman*

T. J. Higgins	S. G. Eskin	G. Werbizky

■ This translation of the Soviet Journal *Izmeritel'naya Tekhnika* is published and distributed at nominal subscription rates under a grant in aid to the Instrument Society of America from the National Science Foundation. This translated journal, and others in the Series (see back cover), will enable American scientists and engineers to be informed of work in the fields of instrumentation, measurement techniques, and automatic control reported in the Soviet Union.

The original Russian articles are translated by competent technical personnel. The translations are on a cover-to-cover basis and the Instrument Society of America and its translators propose to translate faithfully all of the scientific material in *Izmeritel'naya Tekhnika*, permitting readers to appraise for themselves the scope status, and importance of the Soviet work. All views expressed in the translated material are intended to be those of the original authors and not those of the translators nor the Instrument Society of America.

Publication of *Izmeritel'naya Tekhnika* in English translation started under the present auspices in August, 1959, with Russian issue No. 1 of Jan.-Feb. 1958. The program has been continued with the translation and printing of the 1959-1961 issues, which are monthlies.

Transliteration of the names of Russian authors follows the system known as the British Standard. This system has recently achieved wide adoption in the United Kingdom, and is currently being adopted by a large number of scientific journals in the United States.

Readers are invited to submit to the Instrument Society of America comments on the quality of the translations and the content of the articles. Pertinent correspondence will be published in the Society's monthly publication, the ISA JOURNAL. Space will also be made available in the ISA JOURNAL for such replies as may be received from Russian authors to comments or questions by the readers.

1961 Volume Subscription Prices:

Per year (12 issues), starting with 1961, No. 1

General:	*United States and Canada*	$25.00
	Elsewhere	28.00
Libraries of nonprofit academic institutions:		
	United States and Canada	$12.50
	Elsewhere	15.50
Single issues to everyone, each		$ 6.00

1958, 1959, and 1960 issues also available. Prices upon request.

See back cover for combined subscription to entire Series.

Subscriptions and requests for information on back issues should be addressed to the:

Instrument Society of America
530 William Penn Place, Pittsburgh 19, Penna.

Translated and printed by Consultants Bureau Enterprises, Inc.

Copyright © 1961 by the Instrument Society of America

EDITORIAL BOARD OF IZMERITEL'NAYA TEKHNIKA

G. D. Burdun *(Editor)*
I. I. Chechik *(Asst. Editor)*
V. I. Ermakov
N. M. Karelin
M. I. Levin
G. N. Sharonov
L. M. Zaks
M. K. Zhokhovskii

Measurement Techniques

A translation of Izmeritel'naya Tekhnika, a publication of the Academy of Sciences of the USSR
Russian Original Dated June, 1961

1961, No. 6, pp. 427-514 December, 1961

CONTENTS

	PAGE	RUSS. PAGE
LINEAR MEASUREMENTS		
Certain Changes in the Regulations for Checking and Using Block Gauges. L. K. Kayak	427	1
Automatic Measuring of Dimensions in Turning. N. I. Novikov and B. K. Makarevich	431	5
Checking the Readings of a Double Microscope MIS-11 by Means of Block Gauge Steps. V. V. Pen'kov and Z. K. Antyufeeva	433	7
Investigating the Accuracy of Evolventometers. G. S. Simkin and G. Ya. Gafanovich	435	8
MEASUREMENTS OF MASS		
Reorganizing the Use of Unit of Mass Standards. N. A. Smirnova and N. M. Rudo	439	10
Modernization of DS-800 Scales. R. B. Masyukov	442	13
MEASUREMENTS OF TIME		
Reference Equipment for Reproducing and Measuring Small Intervals of Time. D. P. Markovskii	443	16
MECHANICAL MEASUREMENTS		
Experience Gained in Using Universal UTS1-VT-12 Strain Gauge Sets. Yu. N. Samoilov	446	16
Low-frequency Vibrometer with a Liquid Seismic Mass. V. V. Neshukaitis and S. É. Valteris	448	18
Strain Gauge Dynamometer. L. G. Étkin	451	21
THERMOTECHNICAL MEASUREMENTS		
Electroacoustic Gas Thermometer for the Low Temperature Range. A. D. Brodskii	453	22
Standard Table for the Isobar Thermal Capacity of Benzoic Acid in the Range of 10-350°K. A. A. Sklyankin, P. G. Strelkov, and V. N. Kostryukov	455	24
Testing Equipment for Determining the Parameters of Heat Radiation Receivers. A. F. Mal'nev and L. S. Kremenchugskii	458	26
Simple Method of Equalizing the Temperature Field of Tubular Resistance Furnaces. B. K. Bragin	462	30
ELECTRICAL MEASUREMENTS		
New Model of a High-resistance Six-decade Potentiometer. T. B. Rozhdestvenskaya, D. I. Zorin, and A. M. Brodskii	464	31
Obtaining a Given Phase Shift between Voltages by the Beating Method. E. D. Koltik	469	36
Measurements of Wattless Power and the Power Factor with a Nonsinusoidal Current and Voltage. P. B. Usatin	472	38
Basic Properties of Electromechanical Phase Meters. E. S. Polishchuk and A. D. Nesterenko	477	41

CONTENTS (continued)

	PAGE	RUSS. PAGE
Effect of Nonlinear Distortions on the Error in Measuring a Phase Difference between Two Voltages. B. G. Kaduk	480	44
MEASUREMENTS AT HIGH AND ULTRAHIGH FREQUENCIES		
Equipment for Testing Frame-type Field-strength Measuring Sets by Means of a Reference Induction Field. V. S. Buzinov	484	46
Frequency Checking by Means of High-Q Quartz-crystal Resonators. L. D. Bryzzhev	487	48
MEASUREMENTS OF VOLUME		
Checking Autosaturators and Automatic Machines for Measuring Out Aerated Water. A. N. Pavlovskii	491	50
MATERIAL RECEIVED BY THE EDITORIAL BOARD		
New Principles for Determining Compulsory State Testing of Measuring Instruments. V. D. Alesin	495	53
New Ideas for Repairing and Testing Measuring Instruments in Rural Localities. G. V. Savchenko	498	56
REVIEWS AND REPORTS		
Testing Conveyor Scales	500	57
INFORMATION		
Danish Vibration-measuring Apparatus	502	58
Meetings and Conferences on Measurement Techniques	503	59
International Metrological Conferences	504	59
Symposium on Temperature Measurements Held in USA. E. T. Chernyshev	505	60
Organization and Methods of Technical Inspection	506	60
REVIEWS		
Handbook on the Technique of Linear Measurements. P. Leinveber	507	61
FOR THE JOURNALS	510	63
In the Committee of Standards, Measures and Measuring Instruments	513	64

LINEAR MEASUREMENTS

CERTAIN CHANGES IN THE REGULATIONS FOR CHECKING AND USING BLOCK GAUGES

L. K. Kayak

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 1-5, June, 1961

The plane-parallel end gauges of length (which we shall henceforth for simplicity call block gauges) are one of the most accurate means of measuring length, and are widely used not only for commercial measurements of dimensions, but also for reference measurements and checking of various gauges and instruments and transferring the value of units from primary standards to reference gauges and measuring instruments. In order to provide the required accuracy for this transfer, certain grades of block gauges have been established.

The procedure for grading block gauges and transferring the values of units of length is specified in the testing circuit [1].

According to the new definition of the meter adopted by the 11th General Conference on Weights and Measures in October, 1960, the basis for all measurements of length made with block gauges and measuring instruments consists of the standard method of transferring the unit of length expressed in wave lengths of the krypton-86 orange line, and not the natural cadmium red line which was previously used.

The specifications for the manufacture of block gauges, regulations for their testing and use were determined during the last 20 years by the well-known OST (All-Union Standard) 85000-39. The establishment of this OST has been of great importance for ensuring unified measurements in industry. However, since the establishment of OST 85000-39 our industry has not only greatly increased its output, but has also developed technically. More accurate technical measurements are now required; new measuring methods and measuring instruments have been developed. It has, therefore, become necessary to raise the accuracy of block gauges.

Since January 1, 1961, the OST 85000-39 has been replaced by the GOST (All-Union State Standard) 9038-59 "Plane-parallel end gauges of length." The old standard contained, in addition to the technical requirements for block gauges, also instructions for their application and testing. The new GOST only contains the technical requirements for newly manufactured block gauges. The regulations on applying and checking block gauges are specified in instruction 100-60, which has been approved by the Committee of Standards, Measures, and Measuring Instruments and also came into force on January 1, 1961.

In the new standard, contrary to the old one, provision is made for the manufacture of Grade 4 instead of Grade 5 block gauges. Moreover, in view of the improved production technology, it can be assumed that in the near future block gauges only of the top three grades of 0, 1, and 2 will be manufactured.

The grades specified by GOST 9038-59 are approximately the same as those of OST 85000-39 with respect to the tolerances in the mean length deviations of block gauges. The values of tolerances have been slightly reduced only for some of the gauges in different grades.

The tolerances established by the standard for the deviations of the mean length of block gauges are guaranteed tolerances, since they include the maximum measuring method errors.

GOST 9038-59 enforces the industrial production of 15 different sets of block gauges (the cancelled OST 85000-39 did not specify the range of gauge blocks), including special block gauge sets intended for checking universal measuring instruments without the use of gauge blocks. Micron gauge sets of 1.991-2 and 2-2.009 mm suitable for more precise measurements than the sets of 0.991 to 1.009 mm will also be manufactured.

Moreover, the GOST also provides for the manufacture of separate block gauges of all grades of accuracy. The latter provision is very important since it will save the plants the considerable expense involved in repairing worn block gauges.

The value of tolerances for the parallelism of manufactured block gauges has been reduced on an average by 1/3 as compared with the old standard.

The ringing effect in block gauges is specified, in addition to the existing method of lapping them to glass plates, also by checking the adhesive force of two gauges in a block by the sheering effort required to separate them. This has made it possible to specify quantitatively the ringing effect; for instance, for grade 0 gauges the sheering effort should not be less than 4 kg-wt. The checking of the block gauge ringing effect by means of the sheering effort is compulsory for newly manufactured gauges.

The accuracy of block gauges to a very great extent depends on the stability of their length with time. In certain cases investigations have shown considerable variations (up to several μ/m) with time in block gauges [2, 3]. The OST 85000-39 tolerated a possible variation over one year in the length of grade 0 block gauges amounting to 1.5 μ/m, and for gauges of the remaining grades up to 3 μ/m. In the new standard these tolerances have been reduced to 1/3 of the former value for grades 0 and 1, and to 1 μ for grades 2 and 3.

Even greater stability of block gauges now becomes necessary in view of the new definition of the meter, which raises considerably the accuracy in reproducing a unit of length. In order to transfer this increased accuracy to commercial measurements, it is necessary to have high quality reference gauges.

Instruction 100-60 establishes the general specifications for checking block gauges in use, and those supplied by the manufacturers and repair workshops.

Block gauges become worn in use and the grade of their accuracy is lowered, but they remain suitable for less accurate measurements. Instruction 100-60 establishes, therefore, additional grades 4 and 5 with appropriate tolerances for block gauges which are in use and whose median length exceeds the tolerances established by GOST 9038-59 for grade 3 gauges. Grade 4 and 5 gauges correspond in their accuracy to grade 4 gauges certified by Table 4 of the former standard.

Instruction 100-60 divides reference block gauges into 5 grades according to the testing procedure for block gauges. Although precision requirements in linear measurements have become more exacting, and the number of measuring instruments checked by means of block gauges has increased, it has been found advisable to reduce the number of grades for reference block gauges, thus reducing the number of steps in the measuring procedure for transferring a unit of length.

Instruction 100-60, like the measuring procedure for block gauges, stresses more clearly than before the part played by reference block gauges. The grade of accuracy forms the basic characteristic of commercial block gauges, whereas that of reference gauges consists in their measuring circuit assignment.

Instruction 100-60 establishes the methods, means, and temperature conditions for checking block gauges and determines the normal conditions for their checking and use, which consist of a temperature of 20° C, pressure of 760 mm Hg, a vertical measuring position for gauges up to 100 mm, and a horizontal position for gauges over 100 mm. If the measuring conditions differ from the normal ones, the measurements must be corrected.

The value of a block gauge is taken as its median determined by GOST 9038-59 as the length of a perpendicular dropped from the middle of one of its measuring surfaces onto the opposite surface. This determination of a block gauge length differs from that adopted in OST 85000-39. Since in measuring the length of block gauges by means of an absolute interference method the gauges are normally lapped to an auxiliary plate, the above condition may also be considered as normal. If the auxiliary plate is made of a different material than that of the gauge, or its surface finish differs from that of the gauge, the interference measurements must be corrected for the difference in the gauge and plate surfaces. At present, steel, quartz (of the crystal or fused type), and glass plates are used for this purpose. The types of auxiliary plates to be used with block gauges of different grades, and the measurement corrections to be applied are given in test method instructions which are now being redrafted to conform with the principles laid down in instruction 100-60.

The accuracy of the reference graded block gauges is characterized by the maximum error with which their median length is known. The actual value of a block gauge median length is determined in checking by any of the methods and is entered in its certificate which remains valid up to the next checking. It has already been stated that the length of steel block gauges may vary with time. These variations are normally unknown and cannot be allowed for in corrections. The tolerances established by instruction 100-60 for errors in block gauge median lengths include, therefore, both the limiting error of the testing method and the possible variation of the gauge length be-

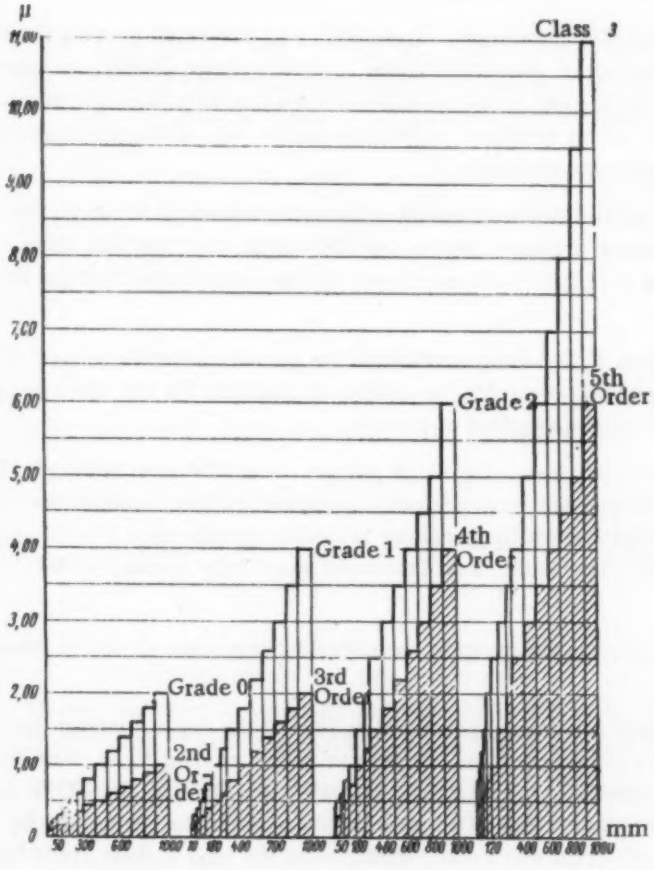
tween routine checking periods. The generalized formulas provided in the instruction for calculating approximate tolerances for the actual value of the gauges' median length should only be considered as indicating the respective grades of reference gauges, but should not be used for determining measuring method tolerances.

In compiling instruction 100-60 it was considered advisable to retain the tolerance formulas for gauge grades which are given in OST 85000-39 and have proved their value over many years of practical application.

$$\delta_{t_1} = \pm (0.05 + 0.5\,l)\,\mu,$$
$$\delta_{t_2} = \pm (0.07 + 0.7\,l)\,\mu,$$
$$\delta_{t_3} = \pm (0.1 + 2\,l)\,\mu,$$
$$\delta_{t_4} = \pm (0.2 + 3.5\,l)\,\mu,$$
$$\delta_{t_5} = \pm (0.4 + 5\,l)\,\mu,$$

where l = the gauge length in m.

These formulas, which represent the accuracy of graded reference measures, meet commercial measuring requirements and in the majority of practical cases provide a somewhat increased value for tolerances. Moreover, the permissible median length deviations of grade 0 gauges are equal, as before, to the median length tolerances of 3rd order gauges, deviations of grade 1 gauges to 4th order gauge tolerances, and those of grade 2 to 5th order tolerances (see figure).



The parallelism requirements for 1st and 3rd order gauges in instruction 100-60 are stricter than those of OST 85000-39. Moreover, the tolerances of 1st order gauges correspond to those of grade 0 gauges, those of 2nd order to grade 1 tolerances, and those of the 3rd order to grade 2 tolerances.

With the existence of reference block gauge sets of 5 orders (for checking gauges and instruments) and commercial block gauge sets of 6 grades of accuracy (for direct measurements of dimensions), it is always possible to select gauges for the required accuracy of measurements. Moreover, the testing procedure [1] provides, as a rule, a threefold margin of accuracy when transferring from reference gauges of any order to commercial gauges or instruments. However, in those cases when the measuring method errors are small as compared with the initial gauge errors, a twofold margin of accuracy is permitted.

In certain routine technical measurements (precision instruments, watch and bearing plants) it is necessary sometimes to use commercial block gauges certified with the accuracy of 1st order gauges, whereas the basic purpose of 1st order reference gauges has consisted to date only in checking grade 0 or 2nd order block gauges.

The methods for checking 1st order gauges are very labor-consuming and it is, therefore, advisable to retain their present application, but at the same time raise the accuracy of grade 0 and 2nd order block gauges. In practice this will be completely adequate to meet the raised requirements with respect to accuracy of commercial measurements. Instruction 100-60 provides if necessary the attestation of block gauges with a tolerance of $\pm (0.03 + 0.5\,l)\,\mu$, which is smaller than that provided for 1st order gauges. The accuracy of 2nd order gauges can be raised correspondingly. The accuracy in checking 2nd order gauges by means of comparative contactless methods can be raised up to the existing accuracy of 1st order gauge measurements.

Investigations carried out by the VNIIM (All-Union Scientific Research Institute of Metrology) and the KhGIMIP (Khar'kov State Institute of Measures and Measuring Instruments) show that there are available margins for raising the accuracy of checking 1st and 2nd order gauges. The transition to the new definition of the meter extends these possibilities. However, in order to implement these possibilities it is necessary that the certified gauges should not only retain their length with respect to time, but should also surpass in their quality of production the requirements of grade 0 gauges. Even the most precise measuring method cannot guarantee a certified accuracy for block gauges higher than that of the 1st order if the length of the gauges changes in one year by 0.5 μ/m or if their measuring surfaces deviate from parallelism or flatness by an amount greater than the above value.

Gauge sets suitable for certifying as reference gauges of the 1st and 2nd orders can be obtained by special selection and preliminary measurements. Their lengths should not vary in one year by more than 0.1-0.2 μ.

All the above reasoning regarding the meeting of the raised industrial requirements by increasing the precision of block gauge measurements should only apply to gauges of higher orders and grades. There is no necessity to raise the accuracy of lower order and grade block gauges, since they are normally intended for checking comparatively low precision gauges and instruments and their accuracy fully meets the requirements of production measurements.

In checking gauges and instruments by means of reference gauges it is normal to account for the actual gauge length values and introduce appropriate corrections. If, however, reference gauges are made up with high grade gauges whose permissible actual length deviations from the nominal value do not exceed the tolerances of the corresponding order, it is possible in certain cases to check by means of such gauges without introducing corrections. For instance, if grade 0 gauges are certified as 3rd order reference gauges, etc.

When evaluating the error in transferring the value of a unit length, especially in higher grade gauges, it will be more correct to take as a basis the actual errors of any block gauge measuring method without taking into consideration the errors due to the instability of their lengths, instead of the formulas for the graded gauge tolerances. Such limiting errors will characterize more reliably the actual accuracy in transferring the unit of length values, especially if the selected block gauges are certified as reference standards.

The value of the block gauge median length deviation from its nominal value is not essential in certifying gauges as reference standards of any order and, hence, grade 4 gauges can be certified as 1st, 2nd, and 3rd order gauges, providing that their deviations from flatness and parallelism do not exceed the tolerances specified for the particular order in Table 2 of instruction 100-60.

Instruction 100-60 provides, according to the degree of accuracy established for graded reference gauges, the use of corresponding checking methods and temperature conditions. All the equipment required for the block gauge measuring methods recommended by instruction 100-60 can be supplied at present.

The VNIIM has developed and made interferometers for measuring block gauges up to 1200 mm in length. The quadratic mean error of the most accurate reference method measurements made by means of these interferometers amounts to $\pm 5 \cdot 10^{-8}$. There also exist comparator interferometers for checking 2nd order gauges up to 1 m in length. Such interferometers have been made for the Committee's institutes. Test laboratories are fully stocked with IKPV and IKPG interferometers (GOST 8290-57).

Instructions on the application of reference block gauges are given in the checking procedure [1] and in directions on testing the corresponding gauges and instruments.

In checking commercial sets of block gauges graded according to instruction 100-60 the same methods should be used as for checking reference gauges. Moreover, the tolerances of the respective orders amount to no more than 2/3 (in the majority of cases 1/2) of the median length deviations from its normal value specified by the GOST (see figure). Since the umpire checking of block gauges according to the GOST specification should be carried out by more precise methods, the instruction recommends in such cases that testing methods for the next highest grade be used, and for grade 0 – methods specified for 1st order gauges. In this case the limiting error in the actual value of the block gauge median length will not, as a rule, exceed 1/3 of the median length deviation tolerances, and since the tolerance formula includes the possible instability of the gauge length, the actual ratio of tolerances will be even smaller.

Certain difficulties may arise in umpire testing of grade 0 gauges, since for this purpose it is necessary to use a labor-consuming interferometer method of measurement. This difficulty can be overcome, however, if instead of 1st order gauges, designed for checking grade 0 gauges by means of the comparison method, stable block gauges are used which have been certified with an accuracy higher than normal.

Since commercial sets of block gauges are not intended for checking gauges or instruments and they are not assigned to any grade, their certificate (supplied at the customer's request) should indicate their tolerances.

In order to check the condition of the interferometer equipment in the Committee's institutes, the VNIIM compares every year the measurements of 1st order block gauges made by means of the above equipment at the institutes with the measurements made at the VNIIM. These checks have shown that for 100 mm gauges the differences in measurement seldom attain ± 0.05 μ, and it can be considered that the measurement error of the absolute method does not exceed ± (0.03-0.04) μ [4]. During these measurements the temperature does not deviate from 20° C by more than 0.2° C, the temperature of the gauges is measured with an error not exceeding 0.01° C, and the linear expansion temperature coefficient is known with an error not exceeding $\pm 0.1 \cdot 10^{-6}$ deg^{-1}.

A combined processing of measuring results over several years has shown that the maximum error of the absolute method of measuring block gauges does not exceed $(0.02 + 0.2\,l)$ μ. If the possible variation in the length of block gauges is assumed to be 0.2 μ/m, then formula $\delta_{t_1} = \pm (0.02 + 0.3\,l)$ μ will represent the error of 1st order block gauges, thus confirming the considerations previously expressed as to the possibility of raising the accuracy of block gauge measurements.

During the last two years the manufacturing plants have been preparing to work to GOST 9038-59, and it is to be expected that the quality of our block gauges will improve considerably in the near future. The introduction of the new regulations for checking reference block gauges and the wide application in measurement practice of interferometer instruments will ensure uniform and correct linear measurements with the required degree of accuracy.

LITERATURE CITED

1. Testing Procedures [in Russian] (Standartgiz, Moscow, 1960).
2. A. Z. Polkova, Works of the Committee's Institutes [in Russian], No. 47, 107 (Standartgiz, Moscow-Leningrad, 1961).
3. A. Z. Polkova, Izmeritel'naya tekhnika, No. 12 (1959).
4. E. P. Alekseeva and O. Yu. Shoshina, Works of the Committee's Institutes [in Russian], No. 47, 107 (Standartgiz, Moscow-Leningrad, 1961).

AUTOMATIC MEASURING OF DIMENSIONS IN TURNING

N. I. Novikov and B. K. Makarevich

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 5-6, June, 1961

Analysis has shown that 34% of the time required for turning an article on a lathe is spent on auxiliary operations, including 25% on measurements by means of universal gauges. Hence, the most important task for raising the productivity of checking consists in developing automatic methods for measuring during machining.

The TsNIITMASh (Central Scientific Research Institute of Technology and Engineering) has developed* a new device with a running roller for automatic measuring of external diameters on lathes.

Running roller 1 (Fig. 1), which contains inside it an induction transducer, is pressed against the measured article 2 and rotates together with it.

The roller is mounted on the back slide 3 and is approached to the measured detail by means of the slide feed screw. The pressure of the roller against the measured detail is adjusted by a spring. The induction transducer generates ac signals whose frequency depends on the rotation speed of the detail, the roller diameter, and the number of teeth in the induction transducer. These signals are transformed in the shaping unit into short voltage pulses which are fed to a pulse counter.

*Engineers A. Ya. Peliks and É. L. Abramzon participated in this development.

For each revolution of the transducer the phase of the signal changes a determined number of times as a function of the transducer's angle of rotation. The instruction to begin and end the counting of pulses is provided by a contactless revolution marker 4, which consists of two coils with a permanent magnet whose magnetic circuit is closed through a link placed on the faceplate of the lathe. The link rotates together with the mandrel and closes the magnetic circuit at each revolution. The closing of the magnetic circuit of the coil produces a signal which is transformed into a short pulse and fed to the revolution counting circuit. The revolution counter produces one signal for a complete turn of the detail.

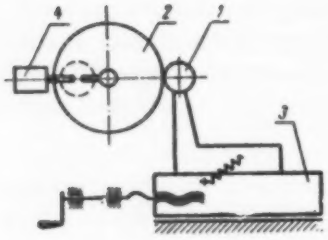


Fig. 1.

The transducer (Fig. 2) consists of two geared rings 1 and 2, which can rotate independently of each other. The Π-shaped groove of ring 2 carries a winding 3, fed with a direct current. The leading-out conductors are taken through the hollow supporting axle 4.

A rise in the diameter of the detail will produce an increased rotation angle of the transducer for a given number of revolutions of the detail, thus producing a larger number of signals which are recorded by the electron counter. The induction transducer thus developed provides 840 signals per revolution for a running roller 210 mm in diameter.

The basic equation for determining the value of one pulse expressed linearly is:

$$A=\frac{D}{N}, \tag{1}$$

where A is the value of one pulse expressed linearly; D is the diameter of the measured detail; N is the number of pulses for m revolutions of the detail.

$$N=nz, \tag{2}$$

where n is the number of revolutions of the transducer for m revolutions of the detail; z is the number of pulses for one roller revolution.

If the roller runs without slipping the following equality will hold:

$$Dm=dn. \tag{3}$$

where d is the roller diameter.

Inserting the value of n from (3) into (1), we obtain

$$A=\frac{d}{mz}. \tag{4}$$

For the transducer under consideration:

$$A=\frac{210}{25\cdot 840}=0{,}01 \text{ mm} \tag{5}$$

We investigated the effect on the accuracy of measurements of the roller pressure (slipping), the speed of the detail rotation, the surface roughness, and the cooling liquid.

By means of these experiments it has been established that stable measuring results are obtained for a roller pressure of 60 kg-wt, and that a further rise of the pressure does not affect the results.

In the transducer type under investigation additional braking in the rotation of the roller is provided by the magnetic field induced in the internal geared ring winding. Therefore, in order to overcome the friction force in the roller bearings and the braking force due to the transducer's magnetic field, it is necessary to press the roller against the detail with an effort of 70-80 kg-wt.

Experiments in determining the effect of the speed of rotation have shown that permissible supply voltage variations of 10% do not produce a jump in the detail's speed of rotation, since the faceplate of the lathe and the detail make a large-size flywheel. However, any wobble in the detail, which it is difficult to eliminate completely, varies periodically the pressure of the roller against the detail, thus changing the friction force between the roller and the detail at a constant force of inertia of the roller. This effect is most pronounced at high speeds of cutting.

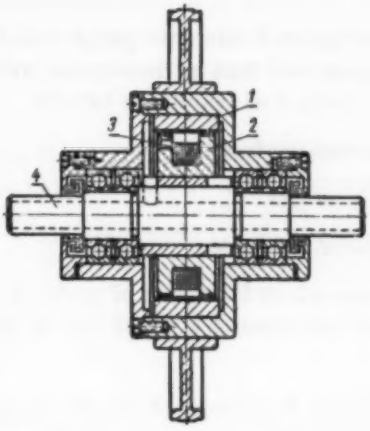


Fig. 2.

Experiments in determining the effect on the accuracy of measurements of the speed of rotation in the range of 20-250 m/min have shown that the dispersion of the measurement results does not exceed 0.03 mm for a roller pressure of 70 kg-wt.

The surface roughness of the detail varied in the range of grade 3 to 6, i.e. the height of irregularities varied in the range of 10-80 μ.

Experiments were carried out at different cutting speeds and with several diameters (200-500 mm).

It has been established that the dispersion of measurement results does not exceed 0.02 mm for surface roughness grades of 5-6, and rises to 0.03 mm for grades 3-4.

Experiments were also conducted in order to ascertain the effect of cooling the liquid (emulsion) on the accuracy of measurements. These experiments have shown that the dispersion of measurement results remains within the limits obtained for measurements without the cooling liquid.

Experiments were carried out on a lathe with 500 mm high centers. The processing of measurement results has shown that the dispersion of random errors follows a normal distribution law; the quandratic mean deviation amounts to 21 μ, thus making it possible to recommend the above automatic method of measurement by means of a running roller for checking details of the 3-3a grade of accuracy.

CHECKING THE READINGS OF A DOUBLE MICROSCOPE MIS-11 BY MEANS OF BLOCK GAUGE STEPS

V. V. Pen'kov and Z. K. Antyufeeva

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 7-8, June, 1961

Owing to the lack of single-line height of irregularity gauges, developed by the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures, and Measuring Instruments), we checked the readings of a double microscope type MIS-11 by means of steps formed from grade 0 block gauges, which were lapped to flat glass plates.

According to Table 4 of instruction 147-58, the attestation error of single-line gauges must be of the grade of 3-9 in the range of ± 0.78 to ± 0.10 μ. Hence, if the error of the method in determining the median length of grade 3 block gauges forming the step amounts to ± 0.1 μ, it is possible that one of the gauges will be determined with an error of + 0.1 μ and the other with an error of −0.1 μ, and then the error in determining the height of the step (the difference in the median dimensions of the two gauges) will amount to 0.2 μ, which is acceptable for certifying grade 3-7 steps.

In order to prevent the error in determining the height of a step made up of grade 8 and 9 gauges from exceeding 0.1 μ, it is necessary to certify the median length of the two block gauges comprising the step by means of

a single reference grade 2 gauge. For instance, if a grade 8 step consists of two block gauges with nominal values of 1.008 and 1.005 mm the actual value of their median lengths should be certified by means of a single grade 2 gauge with a nominal value of 1.007 or 1.006 mm, since it is difficult to determine by counting interferometer fringers a difference exceeding 2 μ between median lengths of two gauges. For a grade 9 surface finish a step is made up of two block gauges with a nominal difference of 1 μ.

Thus, the actual values of these gauges can be determined by means of one grade 2 reference gauge with a nominal value equal to one of the above gauges. The median length of each gauge will then be determined with an error of the same sign and not exceeding 0.1 μ, which corresponds to grade 9 in Table 4 of instruction 147-58.

The attached Table provides approximate relations between block gauges used for forming steps.

Each pair of block gauges is lapped to flat glass plates without interference fringes.

The objects are checked by means of gauges which form a step of the appropriate grade.

Instruments with an objective of F = 25 mm are checked by means of gauges which form steps of grades 3, 4, 5, and 6; those with an objective of F = 13.9 mm by grades 5, 6, and 7; with an objective of F = 8.16 mm by grades 6, 7, and 8; and with an objective of F = 4.25 mm by grades 8 and 9.

For ease of operation with the step, and in order to reduce the distance between the images of the slot on either gauge surface, it is necessary to have a lapped surface without a bevel along the two long sides of the gauges.

Grade of single-line gauge finish	Block gauges comprising the step, mm	Height of irregularities according to GOST 2789-51, mm
3rd	1.12-1.07 = 0.05	0.040-0.063
4th	1.12-1.09 = 0.03	0.020-0.04
5th	1.02-1.005 = 0.015	0.010-0.02
6th	1.01-1.002 = 0.008	0.0063-0.01
7th	1.01-1.005 = 0.005	0.0032-0.0063
8th	1.008-1.005 = 0.003	0.0016-0.0032
9th	1.008-1.007 = 0.001	0.0008-0.0016

The instrument is first checked with objectives of F = 25 mm. The glass plate with the lapped block gauges is placed on the co-ordinate table of the instrument; the microscope is focused and set for a sharp image of the slot on the lapped surfaces of the gauges in such a manner that the slot image is perpendicular to the line of demarcation between the two closely fitted long sides of the gauges and is in the center of that line. The cross-hairs of the eyepiece screw micrometer are placed approximately in the middle of the center of vision in such a way that the horizontal cross-hair is parallel to the edge of the slot image. The microscope is focused in such a manner that the slot image is seen with equal sharpness on either gauge.

In the eyepiece of the microscope's screw micrometer we shall see a slot image which will have a gap in the place where the two gauges touch each other; the right-hand side of the slot is due to the difference in the median length of the gauges, i.e. to the height of the step formed by the gauges.

The horizontal cross-hair is then made to coincide with the bottom of the right-hand slot image and the first reading on the eyepiece micrometer is recorded in terms of the thimble calibrations with an estimated error of one-tenth of a division. The horizontal cross-hair is then made to correspond by means of the eyepiece micrometer screw with the lower left-hand image of the slot and the second micrometer reading is recorded; similar measurements are taken by adjusting to the upper edges of the slot.

The height of the step in terms of the thimble scale is determined as the difference of the two readings multiplied by cos 45°. The height of the step is measured three times. It is then measured with a new setting of the microscope. For this purpose the instrument is focused and set once more for a sharp image of the middle of the dividing line between the two closely placed gauges (without displacing the glass plate on the table), and the height of the step is measured three more times. Similar resettings are made at least three times. The height of the step in terms of the thimble scale is determined as the arithmetic mean of 9 measurements.

The height of the step in microns is determined from the formula

$$H_{ms} = a_m C \cos^2 45° = \frac{a_m C}{2} \mu, \quad (1)$$

where a_m is the mean height of the step in terms of the eyepiece micrometer thimble; C is the value of the eyepiece micrometer thimble calibrations according to the objective with which measurements are made, μ.

The instrument is checked in a similar manner with an objective of F = 25 mm by the height of steps of grade 4, 5, and 6. The error of the instrument readings is then calculated for a given pair of objectives from the height of the steps (grades 3, 4, 5, and 6):

$$\sigma = \frac{H_{ms} - H_a}{H_a} \cdot 100\%, \quad (2)$$

where H_{ms} is the height of the step measured by means of the instrument, μ; H_a is the height of the step obtained from the difference of the actual values of gauges taken from their certificates, μ.

The instrument is checked in the same manner with all the remaining objectives.

INVESTIGATING THE ACCURACY OF EVOLVENTOMETERS

G. S. Simkin and G. Ya. Gafanovich

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 8-10, June, 1961

The high accuracy established for measuring wheels by GOST (All-Union State Standard) 6512-58 requires highly accurate measuring equipment for checking these wheels. In this connection, the Khar'kov State Institute of Measures and Measuring Instruments has investigated several evolventometers of foreign make (Table 1) with the object of establishing whether they meet the new requirements.

These evolventometers were selected because they proved in practice to be the best instruments for checking the profile of gear wheels and it was, therefore, advisable to ascertain their applicability in view of the raised requirements of the new GOST.

TABLE 1.

Instrument type	Firm	Number of tested instruments
Individual disc	Fellow	2
Universal cam	Fellow 12M	1
Universal disc and wedge	Vinco-Tool	1
Universal disc and wedge	Michigan tool	1
Universal disc and lever with a recorder	Zeiss	1
Universal disc and lever with a stationary disc	Orcutt	1

Since we had only a few such instruments, it was necessary to select the best means of determining their metrological properties and, in the first place, their accuracy.

In order to determine the accuracy of these instruments, we used the theory of random functions. The specific application of random functions for investigating the accuracy of these evolventometers consists of the following:

The theory of random functions makes it possible to determine the error of instruments under dynamic conditions, i.e. to determine the errors not only due to variations in counting devices and the effect of external conditions, but also to various dynamic deformations which arise in any of the instrument units during operation.

The same theory makes it possible to determine the instrument error with respect to its basic parameter, i.e. in this instance with respect to the angle of involution φ.

It is known from the theory of random functions [1] that if the input of the instrument is fed with a known or unknown function its output will provide, due to errors in various units of the instrument, a new function which will contain both the input function and that due to these errors. Moreover, if the input of the instrument is repeatedly fed with the same constant function, its variations at the output will be determined entirely by the errors of the instrument and the effect of external conditions, even if the function is unknown. If the same constant function is fed to a whole group of instruments, it is possible to determine on the basis of the output function variations the accuracy of this group of instruments.

TABLE 2.

Angles of involution φ	0°	4°	8°	12°	16°	20°	24°	28°
σ_φ, μ								
The whole group of instruments	0	1.1	1.3	1.5	1.9	2.3	2.6	3.1
Group consisting of 5 instruments	0	0.9	1.2	1.5	1.8	2.1	2.2	2.5

TABLE 3.

Instrument type	σ_0, μ
Zeiss	0.5
Orcutt	0.5
Michigan Tool	0.8
Vinco Tool	1.0
Fellow, with an individual disc	1.0
Fellow, universal with cams	1.0

Thus, a repeated determination of the output function of one instrument provides a measure of the instrument's accuracy (the so-called internal convergence). A repeated determination of the output function for a whole group of instruments will provide an evaluation of the error of this group. However, this method will not provide a separate evaluation of the total error for each instrument in the group. By excluding one or two instruments from the group, it becomes possible, however, to determine the error of the remaining instruments and thus evaluate the effect of the excluded instruments. It should nevertheless be borne in mind that this method will be sufficiently reliable if a relatively large number of measurements is made, i.e. if the omitted measurements have a small effect on the error of the remaining group of instruments.

For the above method of determining the error of a group of evolventometers shown in Table 1, two measuring wheels with modules of 4.5 and 6.5 mm were chosen. Each wheel contained accurate cross sections of left- and right-hand profiles of three teeth. These cross sections constituted the input functions. The profiles of these two wheels were repeatedly measured at equal involution angles φ (4, 8, 12, 16, 20, 24, and 28°) with all the above-mentioned instruments. These angles determined the sections of the random output function.

Each profile was measured five times on each instrument in turn. Thus, for every instrument, groups of 60 measurements were obtained for each angle of involution (2 wheels, 3 teeth, 2 profiles, and 5 measurements). For all the instruments and a given angle of involution the measurements amounted to 420.

Without delving into the details of the theory of random functions, which are described in [1] with the particular application to our case given in [2], let us note that the quadratic mean error of the group as a whole and of separate instruments (internal convergence) was determined from the following relation:

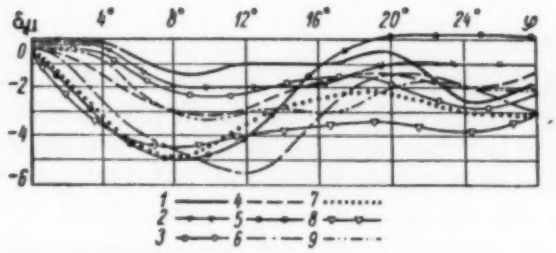
$$\sigma_\varphi = \sqrt{\frac{\sum_{i=1}^{n} [x_i(\varphi) - m(\varphi)]^2}{n-1}}, \tag{1}$$

where

$$m(\varphi) = \frac{\sum_{i=1}^{n} x_i(\varphi)}{n}. \tag{2}$$

$x_i(\varphi)$ are the evaluations of random functions for a given angle of involution; $m(\varphi)$ is the mean value of the random function evaluations for a given angle of involution; n is the number of random function evaluations in a given section.

On the basis of the measurement results and using (1) and (2), we calculated the quadratic mean error σ_φ, both for the entire group of instruments and for the group of five evolventometers (Vinco Tool, Zeiss, Michigan Tool, and Fellow with individual discs, two instruments).



Deviations from the right-hand profile involute of the first gear-wheel tooth obtained for different instruments. 1) Fellow 12M (Universal); 2) Fellow 6057; 3) Michigan Tool; 4) Fellow 6060; 5) Orcutt; 6) UIM-21; 7) Zeiss; 8) Vinco; 9) Michigan Tool.

Table 2 shows the values of σ_φ.

On the basis of the numerical data given in Table 2, the value of σ_φ was determined by the least squares method.

For the whole group of instruments:

$$\sigma_\varphi = 0{,}7 + 0{,}08\ \varphi. \tag{3}$$

For the group of instruments types Vinco Tool, Zeiss, Fellow (with individual discs) and Michigan Tool:

$$\sigma_\varphi = 0{,}7 + 0{,}065\ \varphi, \tag{4}$$

where φ is the angle of involution in degrees.

The quadratic mean error σ_0, which determines internal convergence, is given in Table 3.

As an example, the attached figure shows a graph of output functions obtained for each instrument measuring a single profile of tooth No. 1 of the measuring wheel with a module of 4.5 mm. The same graph shows the measurements of the profile of the same tooth obtained by the blades method on a universal microscope.

TABLE 4.

Evolventometer type \ φ	4°	8°	12°	16°	20°	24°	28°
	σ_0, μ						
Zeiss, universal	0.55	0.45	0.45	0.50	0.50	0.45	0.35
Fellow, with individual disc	0.60	0.90	1.00	1.00	1.15	1.10	1.10
Vinco, universal	0.75	1.10	1.35	1.25	0.95	1.10	0.75
Michigan, universal	0.55	0.55	0.85	0.70	1.00	0.90	0.90
Orcutt, universal	0.65	0.60	0.65	0.80	0.45	0.65	0.60

By comparing the data of Tables 2 and 3, it will easily be seen that:

1. Error σ_φ depends on the angle of involution φ. For the group consisting of five instruments the error is a little smaller than for the whole group.

2. The largest quadratic mean error $\sigma_{\varphi\,max}$ ($\varphi = 28°$) is comparable with the profile tolerance specified by GOST 6512-58. Thus, even the best instruments cannot, strictly speaking, meet the requirements of GOST 6512-58. It is true that the measurement error can be reduced slightly providing the number of tooth profile measurements is increased; however, if measurements are made with one type of instrument its systematic error will not be excluded.

3. The data given in Table 3 show that $\sigma_0 < \sigma_{\varphi\,min}$ and does not depend on the angle of involution φ. This circumstance, it would appear, is due to the fact that σ_0 is in the main determined only by the variations in the counting device readings and by the effect of external conditions, while the other error components are absent.

As a demonstration that error σ_0 does not depend on the angle of involution we provide its value for five types of instruments (Table 4).

The normalized correlation function for the whole group of instruments was also determined by expression:

$$\rho_\varphi = 1{,}0\, e^{-0{,}05\varphi}. \qquad (5)$$

The relatively small coefficient of argument φ indicates the slowly decreasing effect of errors at various angles of involution.

CONCLUSIONS

The measurement results indicate that for checking measuring wheels which are used as standards for grade 5 and 6 wheels (according to GOST 6512-58), as well as for checking involute cams, it is necessary to produce new evolventometers whose kinematic chain must be simple, for instance, as in the Fellow disc instruments. It is also necessary to develop a more reliable method of setting the measuring tip for a given radius of the basic circumference, avoiding the method of setting it by touch.

Such instruments are urgently required by the Committee's metrological institutions and plants which are manufacturing high precision wheels, as well as for checking involution cams designed for checking evolventometers.

LITERATURE CITED

1. V. S. Pugachev, Theory of Random Functions and its Application to Automatic Control Problems [in Russian] (GITTL, Moscow, 1957).
2. G. S. Simkin, Izmeritel'naya tekhnika, No. 4 (1959).

MEASUREMENTS OF MASS

REORGANIZING THE USE OF UNIT OF MASS STANDARDS

N. A. Smirnova and N. M. Rudo

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 10-13, June, 1961

The basic quantity for establishing uniform mass measurements on the territory of the USSR is the mass of the basic USSR standard, the platinum-iridium kilogram No. 12. Up to 1956 the transfer of the value of this mass to reference and then working measures of mass was made by means of the first reference copy, the platinum-iridium kilogram No. 26, and the second reference copy, the platinum-iridium kilogram R_1 (PtIr/1 kg) [1].

Kilogram No. 26 serves to replace the basic standard, kilogram No. 12, when the latter is in the hands of the International Bureau of Weights and Measures. The second reference copy was used up to 1955 for comparisons with the unit of mass working standards.

Up to 1941 the institutes of the Committee of Standards, Measures, and Measuring Instruments had 4 working standards of mass which served to check reference grade 1 weights. These standards were checked against the weight R_1 (PtIr/1 kg) once every two years.

Since the war the requirement in working standards has greatly increased, and their number has been raised to 9, thus considerably increasing the use of the second reference copy. In the near future the number of working standards will increase still further, since the Committee of Standards, Measures, and Measuring Instruments has established many grade 1 State inspection laboratories for measuring equipment, some of which will have to be equipped with working standards of mass, owing to the nature of their work.

Up to 1950 it was aimed to compare the weight R_1 (PtIr/1 kg) with the basic USSR standard not more than once in every 5 years; however, the experience of subsequent years has shown that more frequent comparisons are required. The increase in the number of working standards will require, unless special measures are undertaken, a yearly comparison of the R_1 (PtIr/1 kg) standard with the basic USSR standard, thus producing increased wear of the basic standard and the need for more frequent international comparisons. Such a situation is, obviously, inadmissible, and in order to avoid it, the checking system of the higher order weights and scales has been reorganized.

The necessity for such a reform is also due to the fact that the kilogram R_1 (PtIr/1 kg) as well as the basic USSR standard and all the national prototype kilograms of other countries are made of highly-stable alloy of platinum and iridium [2]. This alloy, however, is expensive, and it is not advisable to make working standards of it.

Both in the USSR and in other countries the working standards of mass are made of less expensive materials. Up to 1955 working standards made of various alloys, mainly of bronze, were used in the USSR. The density of bronze amounts to 8.4 g/cm^3, and that of the platinum-iridium alloy to 21.4 g/cm^3. Hence, the correction for the aerostatic force effect which had to be introduced in comparing the bronze working standard with the copy R_1 (PtIr/1 kg) was very large, amounting to 90 mg. The error in comparing the working standards with this copy must not exceed 0.01 mg, hence, the aerostatic force correction must be determined with an error not exceeding 0.01 mg. Under stable meteorological conditions during the comparison it is difficult, but nevertheless possible, to determine this correction with an error not exceeding 0.01 mg. However, if the air density varies considerably, the aerostatic force correction is calculated on the basis of an assumed mean air density, thus leading to an error exceeding the tolerance. Moreover, owing to variations in the aerostatic force acting on the compared weights, the oscillation of the scales is disrupted, the balanced position "drifts", and the deviations increase. These circumstances made it necessary to make a large number of comparisons (up to 16-20) of each bronze standard with the copy R_1 (PtIr/1 kg) for the purpose of certifying each standard with the required accuracy. In the reorganization this had also to be taken into consideration. The condition of the working standards of mass had also to be improved.

Investigations carried out by the VNIIM (All-Union Scientific Research Institute of Metrology) and abroad have shown that bronze standards with a polished surface as well as with a gilded surface do not meet the requirements specified for the stability of working standards of mass [3, 4, 5]. The variations in the mass of bronze working

standards amounted in one year to 0.7 mg, which is altogether inadmissible. Hence, the substitution of bronze working standards of mass by new, more stable standards is also a pressing problem.

Thus, the improvement of the units of mass affected the copies of the basic USSR standard and involved the production of new working standards with the required stability.

These problems were solved while taking into consideration similar work carried out by the International Bureau of Weights and Measures and by several higher metrological institutions in foreign countries [5, 6, 7].

International practice [7] confirms the correctness of dividing the standards into three categories as is done in the USSR (the basic USSR standard, reference copies, and working standards).

It was found advisable to introduce into the checking system an intermediate link between the working standards and the reference copies in order to preserve the basic USSR standard and its copies. This problem was solved by increasing up to five the number of copies of the basic USSR standard [8]. Moreover, these copies must be of the same "grade" as weights No. 26 and R_1 (PtIr/1 kg).

The material for making the new copies was chosen with a view to providing the greatest stability of their mass and their maximum reliability and accuracy in their comparison with the working standards. The advisability of making the copies of a material of a density approaching that of the working standards is obvious.

The International Bureau of Weights and Measures has conducted for several years investigations of materials for making grade 2 standard units (our copies according to the terminology of the International Bureau of Weights and Measures are classed as grade 2 standards). Less expensive alloys than those of platinum and iridium were used, with a density varying between 19 and 7.8 g/cm^3 [5]. Investigations have shown that making standards of alloys approaching in density the platinum-iridium alloy is not advisable, since weights made of such alloys do not possess a sufficiently high stability. The mass of weights made of stainless steel proved to be more stable. Investigations carried out during 17 years have made it possible to recommend the following types of stainless steel: alloy Uranus 10, consisting of 20% Cr and 10% Ni, and alloy Nicral containing 20% Cr and 20% Ni. The stability of kilogram weights made from these alloys has proved to be satisfactory.

From 1951 to 1954 the VNIIM also conducted experiments on materials for making high precision weights [3]. These experiments showed that weights made of stainless steel Kh18N9T, which contains 18% Cr and 9% Ni, possess the greatest stability of mass. This steel approaches in its composition the alloy Uranus 10, which is recommended by the International Bureau of Weights and Measures.

On the basis of this work, it was decided to make the new copies of the basic USSR standard of stainless steel type Kh18N9T.

It has already been pointed out that bronze working standards are unsatisfactory with respect to the stability of their mass, and it was, therefore, decided to replace them by new ones made of stainless steel type Kh18N9T of the same smelt as the new reference copies. This will lead to the maximum reliability and accuracy in comparing working standards with reference copies, and to the minimum expenditure of labor in their checking. Such a substitution of the existing working standards by new ones is also advisable because at present the reference grade 1 weights, which are compared with the reference standards, are made exclusively of stainless steel. Thus, in calibrating standard weights maximum accuracy will be achieved with the minimum expenditure of labor.

In 1955 the Riga plant "Étalon" made for the VNIIM 17 kilogram weights of stainless steel type Kh18N9T of the same smelt. The weights have the shape of straight cylinders whose height is equal to their diameter. The top phase of each weight is engraved with its number by means of an electrical polisher.

From the above kilogram weights three weights Nos. 6, 8, and 15 were chosen as copies of the basic USSR standard and designated for comparison as V (St/1 kg) No. 6, N (St/1 kg) No. 8, and V (St/1 kg) No. 15.

Weights Nos. 1, 2, 3, 4, 5, 7, and 9 were selected as working standards for the Sverdlovsk branch of the VNIIM, the VNIIK (All-Union Scientific Research Institute of the Committee of Standards, Measures, and Measuring Instruments), the KhGIMIP (Khar'kov State Institute of Measures and Measuring Instruments), the NGIMIP (Novosibirsk State Institute of Measures and Measuring Instruments), the checking and test laboratory of the VNIIM and the Latvian checking and test laboratory of the VNIIM.

Since up to 1957 side by side with stainless steel working standards old bronze standards were also used, it was decided to use temporarily as a copy of the basic USSR standard the thoroughly studied bronze weight of 1 kilogram, designated for comparison purposes as Gor (CuSn/1 kg) No. 12. For the same reason, bronze working standards of mass were temporarily included in the checking system of weights and scales [8].

In 1956 three copies of the basic USSR standard were attested, consisting of weights V (St/1 kg) No. 6, N (St/1 kg) No. 8, and Gor (CuSn/1 kg) No. 12. At the same time, the new copies were temporarily compared with the copy R_1 (PtIr/1 kg), which in 1955 was compared with the basic USSR standard. The copy of the basic USSR standard N (St/1 kg) No. 8 was handed over to the second metrological base in Novosibirsk (NGIMIP), and copy V (St/1 kg) No. 6 was used for checking new stainless steel working standards. As was to be expected, it was not necessary to determine the density of air when comparing the working standards with copy V (St/1 kg) No. 6, since the correction for the aerostatic force effect is sufficiently accurate if it is based on the mean density of air (1.2 mg/cm^3).

Since the difference in the volumes of the weights under comparison approaches zero, the aerostatic force has practically no effect on the oscillations of the scales. Hence, the variations of scales in the above comparisons were considerably smaller than those obtained in comparing bronze working standards with the copy R_1 (PtIr/1 kg).

Owing to the fact that the basic source of systematic and random errors in comparing working standards with copies of the basic USSR standard has been eliminated, the comparison results have become more reliable, the number of comparisons of each working standard with the copy has been reduced to 2/3 or 1/2, and the accuracy of comparisons has been somewhat increased.

In 1959 the copies of the basic USSR standard, with the exception of the temporary copy Gor (CuSn/1 kg) No. 12, were checked against the basic USSR standard. Moreover, the new checking technique developed in 1958 and briefly described in [10] was used.

The comparison of the results obtained in checking the reference copies in 1959 and in 1956 as well as the results of checking working standards in 1956, 1957, 1958, and 1959 indicate good stability of the mass of the new reference copies and working standards made of stainless steel.

The scientific council of the VNIIM approved at its session of December 25, 1956 the new copies and working standards of mass made from stainless steel.

CONCLUSIONS

Despite the fact that since the establishment of the new copies and working standards of mass made of stainless steel type Kh18N9T only four years have passed, it is possible to draw conclusions on the great importance of the reorganization in the sphere of standard units of mass.

The advantages of the above reorganization consist of the following:

1. The necessity of using the basic USSR standard of mass for checking purposes has been greatly reduced. As a result, the basic standard will be preserved for a long time.

2. The stability of the mass of the working standards has been raised. The variations in the mass of the stainless steel working standards for one year's use amounts on an average to 0.02-0.03 mg as against variations in the mass of the old bronze standards amounting to 0.7 mg. This has made it possible to check working standards once every 2 years instead of every year.

3. The checking of working standards of mass has been simplified and at the same time its accuracy and reliability has been increased. The time required for checking has been reduced to 2/3-1/2 of the time formerly required.

LITERATURE CITED

1. Testing Methods, draft [in Russian] (Standartgiz, Leningrad, 1956).
2. A. I. Bonhure, Revue de Metrologie pratique, XI (1950).
3. G. A. Krakhmal'nikova, Trudy VNIIM, No. 27, 87 (1955).
4. Bigg and Bursh, British Journal of applied physics, 2, No. 5 (1951).
5. A. I. Bonhure, Microtecnic, No. 3 (1952).

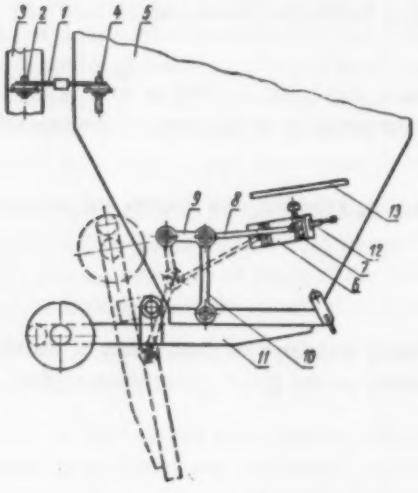
6. Standards of Mass, NBS Technical News Bulletin, 35, No. 1 (1951).
7. M. Jacob, Microtecnic, IV, No. 4 (1950).
8. Testing Methods [in Russian] (Standartgiz, Moscow, Leningrad, 1960).
9. N. A. Smirnova, Izmeritel'naya Tekhnika, No. 4 (1960).

MODERNIZATION OF DS-800 SCALES

R. B. Masyukov

Translated from Izmeritel'naya Tekhnika, No. 6,
p. 13, June, 1961

The experience of using the automatic DS-800 scales for weighing beet at the Dzhambul sugar combine showed that the scoop swings under the impact against its walls of the beet which is fed to it, and that the opening and shutting of its bottom is too abrupt.



The swinging of the scoop very often damages the mechanisms controlling the gate of the feeding hopper and the bottom of the scoop, and jams the reduction gear, thus leading to damage (burning) of the motors.

In order to reduce the swinging of the scoop, the author of this article mounted on the scales cross-braces 1 (see figure) which are adjustable in length and fit on to pins 2 on frame 3 of the scales and pins 4 on the scoop 5. In order to soften the shocks when the scoop bottom is opened and shut, an air cylinder 6 with piston 7 was mounted on the scoop wall (on the opposite side to the counter). Connecting rod 8 of piston 7 is coupled by means of swivelling stays 9 and 10 to the bottom 11 of scoop 5. Cylinder 6 is fitted with an air valve 12, which opens and shuts with the opening and closing of the bottom.

In order to be able to adjust the time required for the bottom to shut, the cylinder is provided with a bolt which regulates the outlet of the air from the cylinder.

In order to protect the cylinder from being hit by the beet which misses the scoop, a guard cover 13 is fitted.

These structural alterations have made it possible to eliminate the aforementioned defects in the operation of the scales.

Editorial Note. The F. É. Dzerzhinskii plant of automatic batching machines should acquaint itself with the structural alterations of the DS-800 scales introduced by the Dzhambul sugar combine and in case of satisfactory operational properties these changes should be incorporated in the mass production of the scales.

MEASUREMENTS OF TIME

REFERENCE EQUIPMENT FOR REPRODUCING AND MEASURING SMALL INTERVALS OF TIME

D. P. Markovskii

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 14-16, June, 1961

The VNIIM (All-Union Scientific Research Institute of Metrology) has developed and introduced in its time and frequency laboratory a reference equipment UMPV-1 for reproducing and measuring short intervals of time. The equipment is used for checking and state testing of microsecond meters and transducers of short time intervals. It provides time intervals of 1 μsec to 1 sec and measures them between 1μsec and 100 sec.

The equipment consists of a cabinet with two electronic chronometers, a generator of small time intervals, and power packs for them.

When generators of small time intervals are being checked, the generator of the UMPV-1 equipment is not used, but the time intervals between the electrical pulses produced by the checked generators are measured simultaneously by the two electronic chronometers of the equipment. The readings of the checked generator are compared with those of the two chronometers.

In checking short time interval meters the generator of the equipment produces the electrical pulses which mark off the required short time interval. This short time interval is measured simultaneously by the checked instruments and the chronometers of the equipment. The instrument readings are compared with those of the chronometers which are considered to indicate the actual value of that interval. The use of two chronometers ensures reliable measurement results.

Basic technical characteristics of the equipment. The time intervals measured by the electronic chronometers are in the range of 1 μsec to 100 sec; the error of the chronometers is: a) when fed with a high frequency from a VNIIM reference generator ± (0.000001% + 1 μsec), and b) when fed from the quartz crystal generator incorporated in the equipment ± (0.002% + 1 μsec); the electrical pulses which mark off the time interval measured by the chronometers can be of any preset polarity, should have a duration of 4 to 10 μsec and a leading edge slope not less than 50 v/μsec; the time intervals produced by the generator are in the range of 1 μsec to 1 sec spaced by 1 μsec.

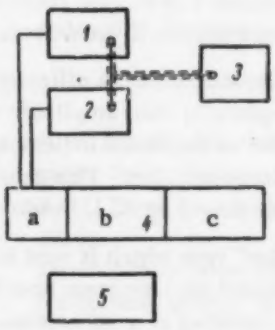


Fig. 1. 1) Electronic chronometer (first); 2) electronic chronometer (second); 3) quartz crystal 1 Mc generator; 4) generator of small time intervals: a) test-type switching panel, b) generator unit, c) capacitor unit; 5) power pack.

By means of additional capacitors, which are connected in parallel with the generator capacitance unit, it is possible to raise the duration of the generated time intervals. A capacitance of 10 μf raises the duration of an interval by 1 sec.

The electrical pulses which are produced by the generator and mark off the small time interval can be of any polarity with an amplitude of the order of 25 v and a pulse duration of 5 μsec. The set operates from 220 v, 50 cps mains; its consumption does not exceed 1.25 kva; its over-all dimensions are 900 x 520 x 1620 mm, and its weight is 250 kg.

Fig. 1 shows the interconnection of various units of the equipment.

The generator of small time intervals comprises the oscillator, the generator capacitance unit made in the form of a separate instrument, and a mercury switch mounted outside the generator on the test-type switching panel.

The operation of the generator is based on the principle of a linear charging of a capacitor up to a potential equal to the operating potential of an electronic relay (Fig. 2).

The circuit operates in the following manner.

In the initial position capacitor C is short-circuited by switch K_1. Switch K_2 is also closed.

When switch K_1 is opened, capacitor C begins to charge and acquires a charge of Q.

$$Q=CU_C=IT. \tag{1}$$

If the voltage at which the electronic relay operates is equal to U_C, the time T during which the voltage across the capacitor rises up to that value is equal to:

$$T=\frac{U_C C}{I}, \tag{2}$$

where C is the capacitance, f; U_C is the voltage, v; I is the current, amp; T is the time, sec.

The time interval T from the instant switch K_1 is opened to the instant the electronic relay operates depends on three circuit parameters. In order to measure the time interval it is convenient to change the value of the charged capacitor C.

The charging current I is set in the current regulator with the aid of the fixed control resistor R (with switch K_2 open and switch K_1 closed) in such a manner that the voltage drop U across this resistor is equal to the operating voltage of the electronic relay.

In this case the value of the charging current will be:

$$I=\frac{U}{R}. \tag{3}$$

If resistor R is now shorted by means of switch K_2 and switch K_1 is opened, and since the value of the charging current I remains constant, it is possible to substitute its value in (2) by that obtained from (3):

$$T=RC. \tag{4}$$

It is not necessary to strive for a high stability of the charging current and the relay operating voltage, since the current is set before measurements. The charging current and voltage must only remain stable for the period between the instant of setting the current and making the measurement.

A sufficiently high stability in time of capacitor C and resistor R can be obtained without difficulty.

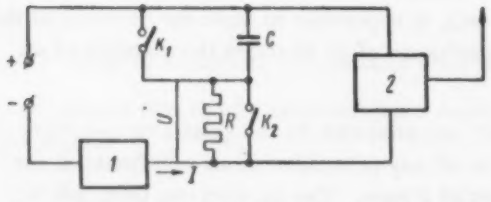


Fig. 2. 1) Current stabilizer; 2) electronic relay.

Once the value of the control resistor R is set, the required capacitances for obtaining various time intervals T are selected.

The generator consists of the following units: a differential circuit for linear charging of the capacitance; two amplitude relays; two paraphase amplifiers; a pulse coincidence indicator; a capacitance unit, and a stabilized voltage rectifier. This generator is a prototype of generator type 495 developed by A. I. Gordienko.

The mercury switch of the "piglet" type which is used in conjunction with the generator, is mounted on a separate board of the test-type switch panel. The measuring capacitance is mounted as a separate unit consisting of a capacitance box which provides any required capacitance in the range of 1 μμf to 10 μf.

Electronic chronometer. Its operation is based on counting the number of periods of high-frequency stabilized oscillations in the measured interval. The chronometer set consists of the electronic counter KhÉ-1, the quartz crystal oscillator GK-5, and the chronometer power pack.

The high-frequency oscillations are supplied to the UMPV-1 chronometer set either from oscillator GK-5 incorporated in the set, or from an external 1 Mc reference oscillator.

In the set one quartz crystal oscillator GK-5 is used for the two electronic chronometers KhÉ-1.

The electronic chronometer KhÉ-1 is made in the form of a separate instrument whose front panel carries control knobs, indicator lamps, and the scales of the electromechanical counter used for counting time intervals. Three supply sockets are mounted at the rear of the chassis for connecting the instrument with the supply source and the high-frequency oscillator.

The schematic of chronometer KhÉ-1 consists of a counting pulse shaper with a repetition frequency of 1 Mc; an input control pulse shaper; an electronic switch ("gate"); four counting decades, and an output device with an electromechanical counter SB-1m for 100 pps.

The chronometer electrical circuit uses 33 tubes types 6N8S, 6N9S, 6N1P, 6N15P, 6Zh2P, 6Zh3P, and 6Kh2P. The counting decades use for their display 28 neon indicating tubes types MN-8 (7 per decade).

After measurements each decade has two lamps alight, namely one of the top ones (the right or the left) and one of the five lamps which are placed lower and bear figures. Of the two figures displayed on a lighted lamp one should read the left or the right one, depending on which of the two top lamps is alight.

The electronic switch serves to transmit the high-frequency (1 Mc) counting pulses to the input of the counting circuit at the instant the starting pulse is received, and to stop their transmission at the instant the stopping pulse is received. The chronometer counting circuit consists of 4 decades and an electromechanical counter. The output device serves to shape and amplify the pulses obtained from the output of the 4th decade, in order to make these pulses suitable for stable operation of the electromechanical counter. Each decade operates with 6 electron tubes, of which the first provides a coding by two, and the remaining 5 form a so-called "ring." The principle of operation of such circuits has been described in sufficient detail [1, 2].

The quartz crystal oscillator GK-5 supplies a voltage of the order of 1 v at a frequency of 1 Mc. It uses a 6Zh8 tube with the quartz crystal connected between the control and screen grids. The oscillator's anode load is aperiodic. This circuit has a higher frequency stability than the normal oscillator circuits with the crystal connected in the anode or grid circuits.

The power pack of the KhÉ-2 chronometer consists of a 450 v full-wave tube rectifier; a dc electronic voltage stabilizer, which provides an output voltage of 300 ± 0.5 v at 60 ma; a dc electronic voltage stabilizer which provides an output voltage of 200 ± 0.3 v at 350 ma; a selenium rectifier which provides 120 v for the biasing circuits; a separate output from the 200 v voltage stabilizer through a dropping resistor for feeding the chronometer anode circuits at 150 v; and a heater transformer with 9 separate windings for supplying heater currents to various parts of the chronometer circuit.

The 220 v, 50 cps mains are fed to the KhÉ-1 chronometer input through two electromagnetic voltage stabilizers SNÉ-220, which maintain the supply voltage practically constant (with an error of ± 1%) despite fluctuations of the supply voltage.

A detailed description of this set is given in the VNIIM Report [3].

LITERATURE CITED

1. N. T. Petrovich and A. V. Kozyrev, Generation and Transformation of Electric Pulses [in Russian] ("Sovetskoe radio" Press, Moscow, 1954).
2. A. M. Bonch-Bruevich, Application of Electron Tubes in Experimental Physics [in Russian] (GITTL, Moscow, 1956).
3. Development of Reference Apparatus for Producing and Measuring Time Intervals from a few Seconds to 1 μsec [in Russian] (Report on project No. R-3/4-58, VNIIM, 1959).

EXPERIENCE GAINED IN USING UNIVERSAL UTS1-VT-12 STRAIN GAUGE SETS

Yu. N. Samoilov

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 16-18, June, 1961

The urgent need for measuring various mechanical parameters of machines and mechanisms under static and dynamic conditions in industry and research institutions may be satisfied to a certain extent by the mass production of the UTS1-VT-12 universal strain gauge sets. These sets are being produced by the Kiev Sovnarkhoz (Council of National Economy). The description of the set [1] should be supplemented by the data obtained in using the equipment for mass testing.

The two years' experience gained in using simultaneously several UTS1-VT-12 strain gauge sets makes it possible to analyze the quality of the equipment and make recommendations for its application.

The mounting of the 12 strain gauge channels together with the master oscillator in a relatively small (720 × × 375 × 280 mm) metal casing is an undoubted structural achievement. Each channel is made as a separate unit plugged into sockets on the rear wall. In case of faults the unit can easily be removed and replaced by a new one. This raises the operational stability of the equipment. The use of a phase-sensitive ring demodulator in the strain gauge circuit should be noted. Owing to this circuit the positive and negative halves of the amplitude characteristics are fully utilized. The sensitivity of channels is varied by adjusting the bridge supply current. The V-12 power pack consisting of a ferro-resonance stabilizer, rectifier and electronic stabilizer is mounted in a compact, easily portable and efficient manner. The system of conductors connecting the strain gauge set with the oscilloscope vibrators, supplies and measuring lines is convenient and well designed.

Side by side with this there exist important defects, some of which are due to the design of the equipment.

The selection of a high carrier frequency of 35 kc for the strain gauge set cannot be justified. This frequency provides an undistorted recording of phenomena with frequencies ranging from 0 to 7 kc. The designers' desire to raise the resolution of the UTS1-VT-12 set up to 7 kc is understandable; however, it is necessary for this purpose to have all the components of the set including the converter, amplifier, and recorder capable of operating up to that frequency. Yet, the recorder, i.e., the vibrator by means of which the oscillographic recording is made, does not meet this requirement. The widely used vibrators I and II for oscilloscope MPO-2 and for various models of the stationary Siemens oscilloscope are designed for recording at 1200 and 2500 cps, respectively. It is true that Siemens vibrators type VII have a higher frequency characteristic; however, they are not widely used owing to their limitations with respect to the permissible recording amplitude.

Various galvanometric vibrators, used for certain types of measurements, also have a limited frequency characteristic. There are certain vibrators with higher frequency characteristics, but they are produced in small numbers on special orders only. Thus, the resolution of the UTS1-VT-12 strain gauge sets amounting to 0-7 kc cannot be utilized, since there are no vibrators covering such a frequency range. Therefore, it would have been advisable in designing the strain gauge set to have taken into account the actually available recording facilities and to have made the carrier frequency of the order of 10 kc. This would have fitted the actual frequency characteristics of the normally used type I and II vibrators. The lowering of the carrier frequency from 35 to 10 kc improves the operational characteristics of the equipment. This change leads to an almost complete disappearance of variable stray capacity couplings due to the displacement of leads which connect the transducers to the strain gauge equipment and often required by the conditions of the experiment.

An annoying omission in the design of the set consists in the absence of a switch in the output circuit of each channel. Hence, in order to switch off a vibrator (with the exception of oscilloscope MPO-2) it becomes necessary to disconnect it at the terminals. The necessity for a frequent switching of vibrators cannot be disputed. It arises in

calibrating transducers, in placing them on the measured object, in damages to the measuring circuits, etc. The lack of the above-mentioned switches subjects the vibrators to an unnecessary possibility of becoming damaged.

The recommendation to use with the UTS1-VT-12 set vibrators types IV and V in addition to types I and II cannot be justified. The use of the former two types is rather risky, since with an unbalanced current of the order of ± 150 ma (due to a break or a short in the transducer circuit) these vibrators are bound to become damaged. In this connection, it would be advisable to use output current limiters which are now widely used in certain strain gauge sets [2].

The calibrating resistances fitted in each channel and intended for maintaining an optimum effort level are designed for use with types I and II vibrators. If vibrators types IV and V are used, the output current in the set channels using calibrating resistors becomes, even at low effort levels, considerably larger than the permissible current for these vibrators.

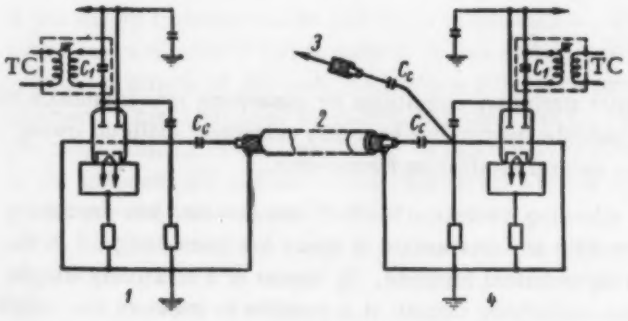
In using the UTS1-VT-12 strain gauge equipment we found the following characteristic defects:

In several channels the geared drive of the tuned reactive elements failed after having been used for a short time only.

In some of the strain gauge sets the master generator transformers were of a low quality, producing insulation breakdown between their windings. Failures in the anode load resistors of the first amplifier tube were recorded. Some of the channels had badly fitting jacks by means of which they are connected to the set supply circuit. This prevented the replacement of channels.

We observed failures in the setting resistors which determined the dc stabilization limits in the electronic stabilizers of the supply circuit. In the supply circuits the ferro-resonance stabilization was disrupted, it would appear, owing to an insufficiently large power transformer.

When several strain gauge sets are operating simultaneously (for instance, when readings are taken at several dozen points of the same object) coupling (interference) arises between the carrier frequencies of the sets. The reason for this interference is due to the fact that the carrier frequencies of the strain gauge sets differ from each other by definite quantities of Δf_1, Δf_2, Δf_3, etc. Owing to the capacitative coupling between the transducers, especially if they are placed on the same object, conditions arise which favor the appearance in the measuring channel of carrier beat frequencies. The beat frequencies modulate the oscillograph recording and measurements become impossible.



1) First equipment; 2) coaxial cable; 3) branching to a third equipment; 4) second equipment.

In order to eliminate this difficulty, we recommend synchronizing all the master oscillators of the operating strain gauge sets, i.e., making all the oscillators coincide in their frequency, phase, and voltage. The oscillators are then interconnected by means of coaxial cable RK-19 or RK-1 into a single system, i.e. they operate in synchronism.

The circuit illustrating the synchronous operation of the master oscillators of several strain gauge sets (see figure) shows that they are interconnected by means of 3-5 m lengths of RK-19 or RK-1 cables. The cables are connected through isolating capacitors of the order of 100-500 $\mu\mu$f, which are selected experimentally when the oscillators are being synchronized.

In readjusting the oscillator frequencies, it is necessary to reset the core of tuned circuit TC and possibly readjust capacitance C_1. The shape of the curve is set by capacitor C-25 [1]. It should be noted that a close coupling between oscillators (a large value of C_C) leads to a reduction in the oscillator output voltage, thus decreasing the sensitivity of the strain gauge set. The oscillators can be adjusted for parallel operation by means of a cathode-ray oscilloscope which should be connected to the output of tuned circuit TC. The above circuit is reliable and stable, and provides an undistorted oscillographic recording. Three sets in parallel were thus used.

The experience gained in operating the UTS1-VT-12 strain gauge sets shows the possibility of using the following types of lines for connecting the transducers with the apparatus. In addition to cables RK-19, it is also possible to use coaxial cable RK-1 and symmetrical cables RD-13 and RD-16, mains television cables KMB-4, as well as lines consisting of sections of the above cables. The maximum length of these lines attained 500 m.

It should be noted that storing and using this equipment in unsuitable, damp, and unheated premises (which is sometimes necessary in field or inspection testing, etc.) disrupts the work of the sets, owing to the failure of single components.

CONCLUSIONS

1. With respect to its assembly and circuitry, the above set is convenient and reliable, and suitable for measuring various parameters of machines and mechanisms.

2. The unjustified selection of a high carrier frequency (35 kc) in designing the set leads to a lowered operational stability.

3. In this article a synchronizing circuit for several strain gauge master oscillators is recommended in order to provide their reliable operation in parallel without any interference or distortions.

LITERATURE CITED

1. N. N. Skvortsov, Izmeritel'naya Tekhnika, No. 4 (1960).
2. S. P. Goncharov, V. V. Kitsenko, A. I. Margulis, and L. G. Chernyavskii, Measurement of Tensions and Efforts [in Russian] (Moscow, 1955).

LOW-FREQUENCY VIBROMETER WITH A LIQUID SEISMIC MASS

V. V. Neshukaitis and S. É. Valteris

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 18-21, June, 1961

Vibrometers with a solid seismic mass can be used under stationary conditions for measuring low-frequency vibrations of a definite orientation in space, but their use as portable instruments becomes extremely difficult owing to the considerable static sagging of the seismic mass at low natural oscillation frequencies.

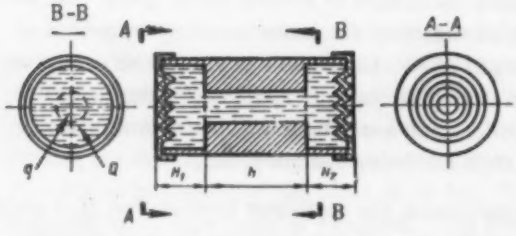


Fig. 1. System with a liquid seismic mass.

A vibration transducer* which can measure low-frequency vibrations with any orientation in space has been designed in the Kaunas Polytechnical Institute. By means of a relatively simple electronic amplifying circuit, it is possible to measure the amplitude and frequency of these vibrations and observe their shape. Further improvements and development of vibrometric equipment of this type is now being carried out in the Electronics and Power Institute of the Academy of Sciences, Lithuanian SSR.

The principle of operation of the vibration transducer is illustrated in Fig. 1. A round tube which is constricted in the middle has its ends closed by elastic corrugated diaphragms. The space between the diaphragms is filled with a liquid. This liquid and the diaphragms constitute the seismic system with suspension springs. The frequency of this system's natural

*V. V. Neshukaitis. Registration certificate No. 7406, 1957.

oscillations can be represented, providing the counteracting moment of the diaphragm is proportional to the sagging of the mass, by the following expression

$$f_0 = F_0 \sqrt{\frac{1+m}{1+mn}},$$

where $m = h/(H_1 + H_2)$ is the ratio of the narrow channel length to the total length of the wide channels; $n = Q/q$ is the ratio of the wide and narrow channel cross sections; $F_0 = 1/2\pi\sqrt{g/s}$ is the natural oscillation frequency of the system without the constriction (g is the acceleration due to gravity, s is the static sagging of the seismic mass in a vertical position of the system).

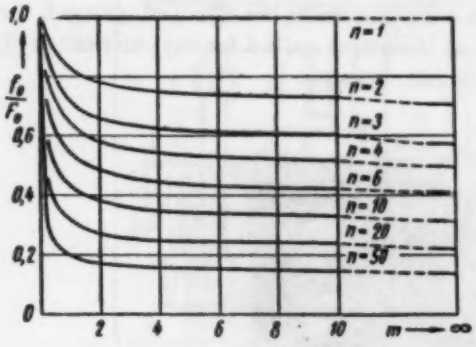


Fig. 2. Relation between the natural oscillation frequency of a system with a liquid seismic mass and the structural parameters m and n.

An analysis of the equation shows that making the value of m larger than 3 in order to reduce the natural frequency of oscillations is of no practical value (Fig. 2). If the condition that $m \geq 3$ is met, the natural oscillation frequency of the system can be represented without a large error by the expression:

$$f_0 = \frac{1}{2\pi}\sqrt{\frac{g}{sn}} \approx \frac{5}{\sqrt{sn}}$$

(here s is in cm, and f_0 is in cps).

Thus, in order to reduce the frequency of natural oscillations the value of n, i.e. the ratio of the channel cross sections, should be raised.

In an actual transducer of this type for an $n = 40$ and $s = 0.2$ cm a natural frequency of 1.8 cps was obtained. This is not a limiting value and depends on the construction of the transducer, and on the values of n and s.

The transformation of mechanical vibrations into electrical signals is attained by means of an air transformer transducer (Fig. 3). The transducer is supplied either through coils 1 and 3 or coil 2 by a high-frequency current. Coils 1 and 3 are connected in such a manner that the magnetic fluxes produced by them, or the emfs induced in them if the supply is connected to coil 2, are in opposition. The output emf amplitude depends on the position of coil 2 with respect to coils 1 and 3, namely in the middle position of coil 2 it is equal to zero, and it is maximum in the extreme positions of the coil. Sometimes it is more convenient to have a neutral point displaced from the middle position. This is attained by connecting capacitor C_1 which carries some of the current from the generator through the output circuit of the transducer. In this case the output signal is produced by the sum of two voltages consisting of the induced emf and the voltage due to the current flowing through capacitor C_1. By adjusting C_1 it is possible to attain the required value of biasing.

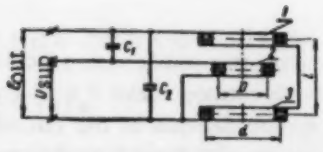


Fig. 3. Schematic of an air transformer transducer with the supplies connected to the middle winding.

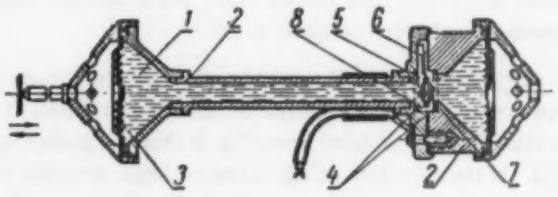


Fig. 4. Construction of the vibration transducer.

By connecting capacitor C_2 in parallel with the output an oscillatory circuit is obtained. If the natural frequency of this circuit coincides with that of the supply frequency, the transducer sensitivity is greatly increased.

The maximum linearity of the characteristic, i.e. of the relation between the output emf and the displacement of the middle coil, is obtained if the following condition is met:

$$D = d \pm 0{,}5l,$$

where D and d are the diameters of the middle and outside coils; l is the distance between the outside coils.

The linearity of the characteristic under this condition amounts to 90% of the distance l.

When coils 1 and 3 are connected in opposition, the transducer becomes insensitive to external magnetic fields, since the emfs induced in them are approximately equal and opposite. If a transducer in a metallic casing is used, the effect of external fields can be completely avoided.

Another version in the design of a vibration transducer with a liquid seismic mass is shown in Fig. 4. The liquid seismic mass 1 fills casing 2, which is closed at both ends by elastic rubber diaphragms 3. The output coils 4 of the transformer transducer are rigidly connected to the casing and the supply coil 5 is suspended on elastic springs 6. The supply coil has a celluloid air-filled float 7 of a size to make the effective specific gravity of the coil and the float equal to that of the seismic liquid.

According to the orientation of the vibration transducer in space the seismic mass will assume a definite position, percolating through special holes 8 in the casing. In a stable-state condition under the effect of springs 6 the supply coil 5 will always be in practically the same position with respect to the output coils 4 for any orientation of the vibration transducer, since its specific gravity is equal to that of the seismic mass.

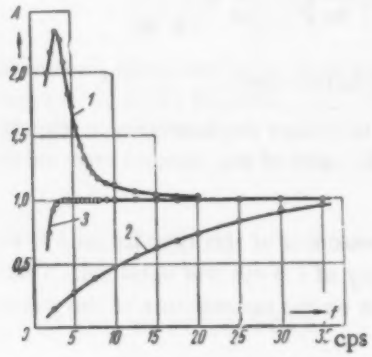


Fig. 5. Amplitude-frequency characteristic of the vibration transducer.

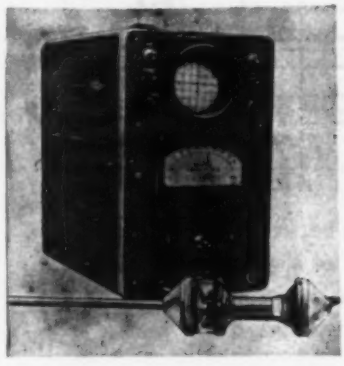


Fig. 6. Appearance of the vibrometer and vibration transducer.

For measuring purposes, the vibration transducer with its probe is pressed by hand against (or fixed to) the measured object. The output coils together with the casing follow the vibrations of the object, but the liquid seismic mass remains stationary and retains the supply coil. The modulated signal obtained at the output of the transducer is demodulated and amplified in an electronic circuit. The amplified signal can be connected to instruments measuring the amplitude or frequency, or to the input of a cathode-ray or loop oscilloscope for observing and recording the shape of vibrations.

The transducer with a liquid seismic mass has a low sensitivity to transverse vibrations, since in the constricted channel the liquid only moves along the transducer axis. Experiments with several transducers have shown that their transverse sensitivity amounts to 2%.

Fig. 5 represents the amplitude-frequency characteristics of the vibration transducer with a liquid seismic mass. Curve 1 was obtained for a system filled with distilled water; curve 2 with glycerine; curve 3 with glycerine diluted by water. It will be seen from Fig. 5 that the damping coefficient of the system depends on the viscosity of the liquid. If the viscosity of the seismic liquid depends on temperature, the system will have temperature errors in the region of its natural resonance. Investigations have shown that it is possible to obtain, by a proper selection of the channel shape, an amplitude-frequency characteristic without a resonance peak if low viscosity liquids are used (distilled water, alcohol), whose viscosity hardly changes over a wide range of temperatures. In such a case the vibration transducer will also be free of temperature errors of that type.

At higher frequencies different portions of the transducer may begin to resonate. This effect, however, can be avoided within the measurement range by an appropriate construction of these parts.

Below we provide a brief technical characteristic of the vibrometer made by the Power and Electrotechnical Institute of the Academy of Sciences, Lithuanian SSR (Fig. 6). The schematic of the vibrometer is shown in Fig. 7.

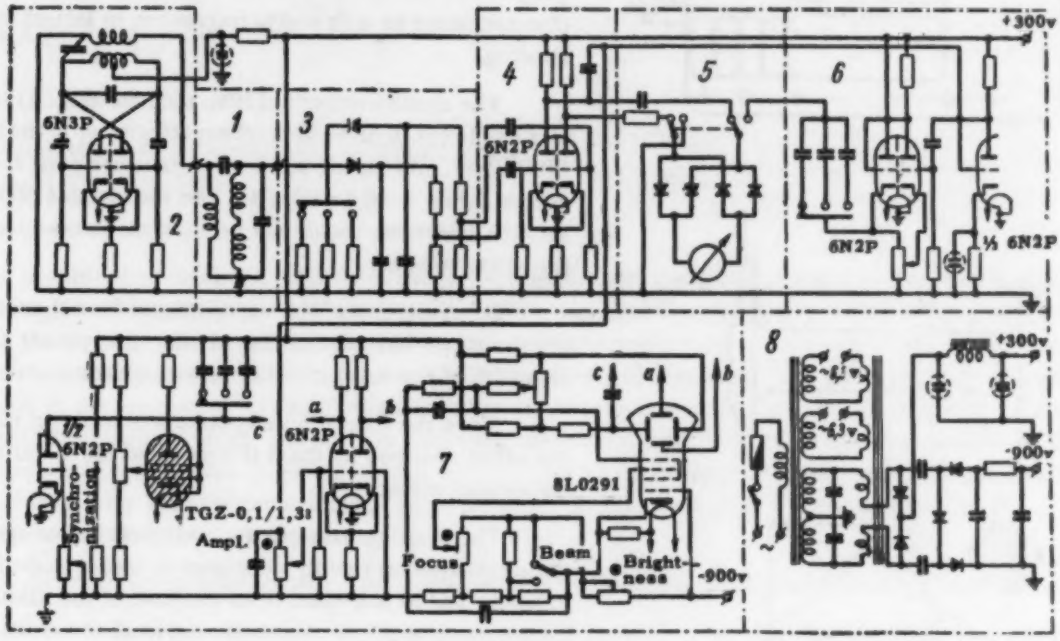


Fig. 7. Schematic of the vibrometer. 1) Vibration transducer; 2) oscillator; 3) demodulator; 4) amplifier; 5) measuring instrument; 6) frequency measuring circuit; 7) cathode-ray oscilloscope circuit; 8) stabilized power pack.

The vibrometer is designed for measuring low-frequency vibrations of various structures, machine details, etc. It has an amplitude range of 1 to 5000 μ and a frequency range of 5 to 200 cps. Its carrier frequency is 50 kc. The vibration transducer is made in two versions, namely, for measuring low amplitude vibrations (see Fig. 4) when it weighs 120 g, and for measuring large amplitude vibrations (see Fig. 6), when it weighs 300 g. The weight of the vibrometer is about 15 kg.

Vibrometers of the above type can be used for measuring low-frequency vibrations of any orientation in space. If semiconductor elements with battery supplies are used, it is possible to produce a miniature, light-weight apparatus of a portable type for measuring vibrations under field conditions.

STRAIN GAUGE DYNAMOMETER

L. G. Étkin

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 21-22, June, 1961

In measuring efforts it is very important to eliminate the results being affected by eccentric applications of loads and lateral forces. The majority of dynamometers are very sensitive to any skewing and lateral forces, thus making their use under production conditions rather difficult.

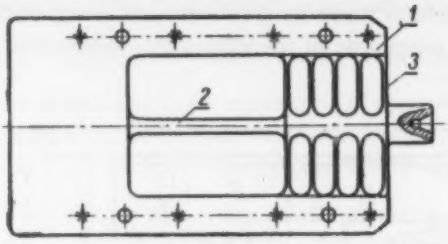


Fig. 1.

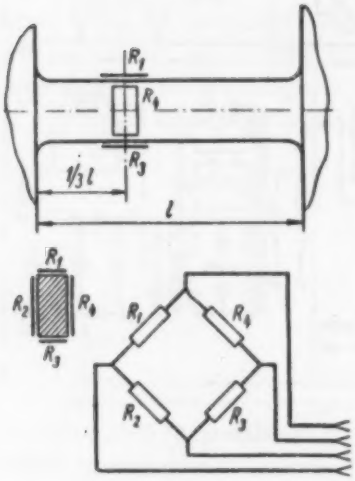


Fig. 2.

The Scientific Research and Design Institute of Test Machines, Instruments, and Equipment for Measuring Mass (NIKIMP) has developed an experimental model of a strain gauge 5 ton-wt dynamometer, which only measures the effort directed along its axis and is insensitive to lateral forces and skewing.

The dynamometer's elastic element (Fig. 1) is made of a single piece of 40 Kh steel heat treated up to the hardness of HRC 35-38. An elastic rod 2 of rectangular cross section is placed inside a rigid casing 1. The rectangular plates 3 absorb the transverse forces and bending moments operating on the dynamometer.

Computations of the experimental model strain gauge dynamometer have shown that all the cross pieces absorb only about 1% of the axial effort impressed on the elastic rod.

Since the cross pieces operate within the elastic range, the effort absorbed by them is accounted for in calibrating the dynamometer.

The bending moment due to lateral forces operating on the dynamometer rapidly decreases in transmission from plate to plate, and at one-third from the base of the elastic rod becomes equal to 0. At this cross section of the elastic rod resistance wire transducers are placed.

Constantan 30 μ resistance wire transducers of 400 ohm with a base of 10 mm fixed to a film of adhesive BF-2 were glued to the elastic rod. The schematic showing how the transducers were glued and interconnected is given in Fig. 2. The method of gluing and interconnecting the transducers adopted in this dynamometer eliminates the effect of the elastic rod on the measuring results.

In testing an experimental model of the strain gauge dynamometer no effects of lateral forces were observed.

Under full load the stresses in the elastic rod amounted to 25 kg-wt/mm^2. Such relatively low stresses provide a linear characteristic and a small hysteresis in the dynamometer elastic element.

The strain gauge dynamometer characteristic is linear in the range of + 0.16 to −0.1%.

The dynamometer was calibrated and its readings checked on a reference 5 ton stationary dynamometer type DOII-5, which had an error of 0.1% of the measured load. These experiments have shown that the error of the strain gauge dynamometer experimental model deduced from 40 tests which were conducted during three months does not exceed 0.3% of the measured load, starting at 0.1 of the maximum scale reading. Variations in the dynamometer readings fall between −0.17 to + 0.1% and −0.5 to + 0.45%.

The dynamometer readings were recorded on an automatic recording instrument with 11 measuring ranges.

THERMOTECHNICAL MEASUREMENTS

ELECTROACOUSTIC GAS THERMOMETER FOR THE LOW TEMPERATURE RANGE

A. D. Brodskii

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 22-24, June, 1961

The possibility of using the relation between temperature and the speed of sound propagation has been previously investigated [1, 2, 3, 4, 5]. At present a new method has been developed [6] of determining temperature by measuring the frequency of oscillations of a sound wave in an acoustic tubular resonator which forms a component part of an electromagnetic oscillations generator with an acoustical feedback. The basic property of such a generator consists in the relation of its oscillating frequency to the temperature of the acoustic resonator. If the tubular resonator is filled with an "ideal gas" (in our case with chemically pure helium), it becomes possible to determine the speed of sound propagation in gas at various temperatures by measuring the frequency of the generator. Modern methods of frequency measurements provide great precision (of the order of 10^{-8}), and hence, a high accuracy in measuring the thermodynamic temperature.

The theory of the electroacoustic gas thermometer is based on the well-known laws of thermodynamics.

The relation between the speed of sound propagation (C) and the absolute temperature (T) has for an ideal gas the form of:

$$C=\sqrt{\frac{\gamma RT}{M}}, \tag{1}$$

where $\gamma = c_p/c_v$ is the ratio of specific heats; R is the gas constant; M is the molecular weight.

If for actual gases [7] only the second virial coefficient B^1 is taken into account, the speed of sound propagation will be

$$C=\sqrt{\frac{\gamma(RT+2BP)}{M}}, \tag{2}$$

where P is pressure.

The fundamental resonance frequency of a constant length tubular resonator is expressed by the formula

$$f=\frac{C}{2L}, \tag{3}$$

where f is the fundamental resonance frequency of the resonator; L is the length of the resonator.

It follows from (2) and (3) that:

$$f^2=\frac{\gamma}{4L^2M}(RT+2BP). \tag{4}$$

By using (4), it is possible to obtain a formula for any thermodynamic temperature

$$T_x=\left(\frac{f_x}{f_0}\right)^2\left(T_0+\frac{2B_0P_0}{R}\right)-\frac{2B_xP_x}{R}, \tag{5}$$

where subscript x denotes the required temperature, and subscript 0 denotes $T_0 = 273.16°$ K.

It is also assumed that for monatomic gases the specific heat ratio γ depends but little on temperature [8, 9]. If the linear temperature coefficient α is taken into account, the thermodynamic temperature can be determined more accurately as

$$T_x = \left(\frac{f_x(1+\alpha t)}{f_0}\right)^2 \left(T_0 + \frac{2B_0P_0}{R}\right) - \frac{2B_xP_x}{R}. \quad (6)$$

It will be seen from (6) that random errors in this method will be determined mainly by the generator frequency measurement errors which, owing to their smallness, can be neglected. The systematic errors depend on the phase relationships in the electroacoustical system, the precision in determining the linear expansion coefficient of the resonator, the accuracy of the virial coefficient values, and the degree of stabilization of the temperature field during measurements. If the monatomic gas used in the resonator is not sufficiently pure chemically, it is necessary to introduce in the formula a correction for the effect of temperature on the thermal capacity of gas*.

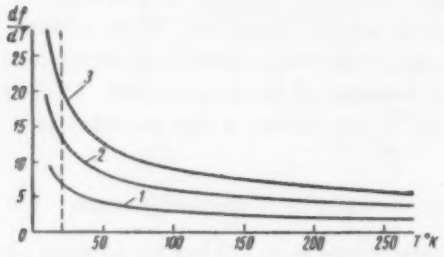


Fig. 1. 1) f_0 = 1000 cps; 2) f_0 = 2000 cps; 3) f_0 = 3000 cps.

One of the advantageous properties of an electroacoustic thermometer is the rise of its sensitivity in the low temperature range. In fact, if we assume that the virial coefficients in (5) are equal to zero, we shall obtain:

$$f_x = f_0\sqrt{\frac{T_x}{T_0}}, \quad (7)$$

whence

$$\frac{df_x}{dT_x} = \frac{f_0}{2\sqrt{T_0T_x}}. \quad (8)$$

It will be seen from (8) that for a T_x approaching zero the sensitivity of this method rises rapidly. The method can also be rendered more sensitive by reducing the length of the resonator, i.e. by increasing f_0. However, this procedure should be used carefully, since a large increase in frequency f_0 increases the attenuation of sound oscillations, and produces sound dispersion in the ultrasonic region. Fig. 1 shows the sensitivity of an electroacoustic thermometer for various values of f_0.

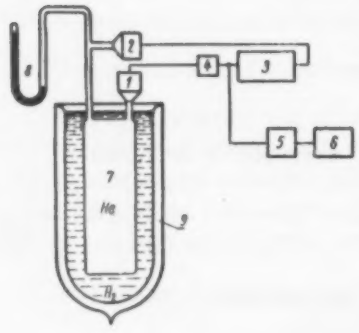


Fig. 2.

Fig. 2 shows a schematic of an electroacoustic thermometer used for determining the boiling point of natural hydrogen. The tube resonator 7 which is 21.6 cm long and 3.5 cm in diameter is filled with chemically pure helium, whose pressure is measured with manometer 8. At a pressure of 760 mm Hg and a temperature of 273.15° K the fundamental resonance frequency is f_0 = 224.06 cps. The resonator is made of a copper tube with a linear temperature coefficient of $\alpha = 12.3 \cdot 10^{-6}$ deg $^{-1}$ in the temperature range of 273.16 to 21.16° K. Audio oscillations are produced in the resonator by means of an electrodynamic telephone 1 and received with an electrodynamic microphone 2 (type MD-58 microphones served as a telephone and a microphone). The microphone and telephone are connected to the tubular resonator by means of 3 mm German silver tubes. Owing to their small diameter, the tubes have a considerably larger acoustic resistance than the tubular resonator and, hence, a smaller Q-factor was found experimentally to be 150. The microphone and telephone were connected to the input and output, respectively, of a wide-band amplifier 3. With such a connection of the microphone and telephone the amplifier began to oscillate at the resonance frequency of f_0. The electroacoustic transducer phases were adjusted by means of phase shifter 4. The Dewar flask 9 was filled with natural hydrogen at normal atmospheric pressure. The required resonance frequency at the temperature of liquid hydrogen was measured by means of a pulse counter 6.

* If the resonator has a sufficiently large diameter and a high Q-factor the Kirchhoff-Helmholtz correction of the speed of sound can be neglected.

Oscilloscope 5 provides visual observations.

The equipment comprises two cylinders of different lengths in order to eliminate systematic errors due to possible phase shifts in the tube resonator, and to provide frequency measurements with an accuracy up to ± 0.1 cps.

The experimentally obtained value for the resonance frequency at the liquid hydrogen temperature in our experiment was equal to f_x = 617.24 cps. From (6) we found the boiling temperature of liquid hydrogen (for generally accepted values of virial coefficients of helium equal to B_0 = 11.48 cm^3/mole and B_x = 4.036 cm^3/mole).

The values of T_x thus obtained agree within 0.03° K with the temperatures obtained by other authors by means of normal gas thermometer methods [10]. At present measurements of the thermodynamic temperature by means of acoustical methods are being used increasingly [11, 12], since the application of radio-frequency methods in thermometry raises considerably the sensitivity of instruments.

The cited results of experimental investigations are provisional.

In our experiment at a temperature of 20° K the sensitivity of the instrument was equal to 15 cps/deg, and the random error of several frequency measurements with each measurement lasting 5 min amounted to ± 0.3 cps. Thus, the random error of measurements did not exceed ± 0.02° K.

The new electroacoustic gas thermometer is intended for determining thermodynamic temperatures in the range of 273.5° to 10° K.

LITERATURE CITED

1. Mayer, On an Acoustic pyrometer. Phil. Mag, XLV, 18 (1873).
2. Quigley, Phys. Rev., 67, 298 (1945).
3. E. W. Barrett and V. E. Suomi, Journ. of Meteorol., 6, 273 (1949).
4. M. Merle, Acustica, 1, 104 (1951).
5. V. Keezom, Helium [Russian translation] (Foreign Literature Press, 1949).
6. A. D. Brodskii, Author's Certificate No. 11970 effective from October 20, 1958.
7. L. Bergman, Ultrasonics [Russian translation] (Foreign Literature Press, 1956).
8. Thermal Constants [in Russian] (Acad. Sci., USSR Press, 1949) p. 855.
9. Handbook "Thermophysical Properties of Matter" [in Russian] (Énergoizdat, Moscow, 1956) p. 8.
10. P. G. Strelkov, Collection of Review Monographs on Measurement Techniques [in Russian] (Standartgiz, Moscow, 1958, No. 5).
11. A. Itterbeek, et al., Temperature Measurement with an Acoustical Thermometer, Bull. de Inst. International du Froid, No. 1 (1958).
12. A. L. Herdig and D. R. Pardue, Thermodynamic Temperature Measurements by Means of the Speed of Sound [Russian translation] (Foreign Literature Press, 1960).

STANDARD TABLE FOR THE ISOBAR THERMAL CAPACITY OF BENZOIC ACID IN THE RANGE OF 10-350° K

A. A. Sklyankin, P. G. Strelkov, and V. N. Kostryukov

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 24-26, June, 1961

Direct calorimetric measurements at low temperatures are widely used for investigating the thermal characteristics of condensed bodies and determining the numerical values of their most important thermodynamic properties (entropy, enthalpy, heat of conversions). To obtain these data accurate measurements are required. In order to discover possible systematic errors and evaluate the accuracy of calorimetric measurements, and sometimes for cali-

Molar Heat Capacity of Benzoic Acid (equalized values). 1 calory = 4.1840 abs. Joule; 0° C = 273.15° K; 1 mole = 122.118 g. The weight of the sample is referred to its value in vacuum.

$T°$ K	C_p cal deg·mole	ΔC_p	$T°$ K	C_p cal deg·mole	ΔC_p	$T°$ K	C_p cal deg·mole	ΔC_p	$T°$ K	C_p cal deg·mole	ΔC_p
10	0,501		46	8,746	0,376	135	18,414		250	29,799	
		0,153			0,360			0,450			0,540
11	0,654		48	9,106		140	18,864		255	30,339	
		0,171			0,344			0,452			0,542
12	0,825		50	9,450		145	19,316		260	30,881	
		0,186			0,329			0,455			0,544
13	1,011		52	9,779		150	19,771		265	31,425	
		0,199			0,314			0,459			0,546
14	1,210		54	10,093		155	20,230		270	31,971	
		0,212			0,301			0,462			
15	1,422		56	10,394		160	20,692		(273,15	32,317)	0,549
		0,223			0,287			0,467			
16	1,645		58	10,681		165	21,159		275	32,520	
		0,231,			0,275			0,472			0,550
17	1,876,		60	10,956		170	21,631		280	33,070	
		0,239,			0,651			0,478			0,550
18	2,116		65	11,607		175	22,109		285	33,620	
		0,247,			0,601			0,483			0,551
19	2,363,		70	12,208		180	22,592		290	34,171	
		0,254,			0,564			0,488			0,551
20	2,618		75	12,772		185	23,080		295	34,722	
		0,521			0,537			0,493			
22	3,139		80	13,309		190	23,573		(298,15	35,070)	0,552
		0,532			0,515			0,497			
24	3,671		85	13,824		195	24,070		300	35,274	
		0,536			0,495			0,502			0,552
26	4,207		90	14,319		200	24,572		305	35,826	
		0,529			0,480			0,507			0,552
28	4,736		95	14,799		205	25,079		310	36,378	
		0,515			0,467			0,510			0,552
30	5,251		100	15,266		210	25,589		315	36,930	
		0,500			0,457			0,514			0,553
32	5,751		105	15,723		215	26,103		320	37,483	
		0,482			0,453			0,518			0,552
34	6,233		110	16,176		220	26,621		325	38,035	
		0,464			0,449			0,522			0,552
36	6,697		115	16,625		225	27,143		330	38,587	
		0,444			0,447			0,525			0,552
38	7,141		120	17,072		230	27,668		335	39,139	
		0,427			0,447			0,528			0,552
40	7,568		125	17,519		235	28,196		340	39,691	
		0,410			0,448			0,531			0,552
42	7,978		130	17,966		240	28,727		345	40,243	
		0,392						0,534			0,553
44	8,370					245	29,261		350	40,796	
								0,538			

Entropy at standard temperature: $S^\circ_{298.15} - S^\circ_0 = 40.04 \pm 0.02$ units of entropy.
Enthalpy at standard temperature: $H^\circ_{298.15} - H^\circ_0 = 5738 \pm 15$ cal/mole.
Note. In order to avoid calculating errors in interpolation, an additional decimal place is given in the table. The final results should be rounded off according to the accuracy of the data indicated in the text.

brating calorimeters, it is possible to use comparative measurements of substances whose specific heat had been studied thoroughly and in detail. Several such substances (including benzoic acid) have been proposed by the American National Bureau of Standards (NBS) [1] for standardizing the relation between specific heat and temperature. In view of the greatly increased calorimetric work, it seems desirable to recommend a similar standard substance in the USSR. It does not seem expedient to use the same substance for low and high temperatures. For instance, the specific heat of aluminum oxide (Al_2O_3, corundum), which in theory can serve as a standard up to about 2300° K, is too small at low temperatures and inconvenient for testing.

In the present work we propose to standardize the table of the benzoic acid's specific heat values in the range of 10 to 350° K. This table is based on detailed measurements carried out by us in 1958-1960.

We selected benzoic acid for several reasons. Its characteristic temperature is sufficiently low ($\Theta_\partial \sim 250°$ K), and its specific heat even at very low temperatures is easily measurable. Benzoic acid is sufficiently stable over the whole of its solid phase. It can be obtained in a sufficiently pure state* and is already being used as a calorimetric standard for measuring the heat of combustion.

*Benzoic acid "for calorimetric and acidimetric measurements" with an impurity content of ≤ 0.01 mole % is produced by the VNIIM.

The proposed table for equalized specific heat values of benzoic acid is based on more than 200 experimental values obtained in the range of 4-395° K in a vacuum adiabatic calorimeter [2].

The temperature above 90° K was measured in International Temperature Scale degrees (OST VKS 6954) and below 90° down to 10° K in degrees of the practical USSR scale [3]. In all the calculations it was assumed that 0° C = = 273.15° K and that 1 calory = 4.1840 abs. Joule.

The equalization of the characteristic curve of C_p versus T was made graphically by means of the first differences. The deviation of the experimental values from the smoothed-out curve followed with sufficient accuracy the random distribution law.

The table has been compiled in such a manner that the intermediate values can be obtained by means of linear interpolation of the function C_p (T) between two adjacent values in the table with an error ≤ 0.1%.

Specific heat values below 10° K are not given in the table, since the existing temperature scales in the range of 4.2-10° K are not reliable.

The values of entropy and enthalpy at a standard temperature are obtained by means of numerical integration on the basis of the table; the specific heat curve was extrapolated to the absolute zero by means of experimental data down to 4° K, and below that figure by means of the proportional law of limits T^3.

The analysis of the results and their comparison with other works [1, 4, 5, 6, 7] provide sufficient grounds to assume that the specific heat values for benzoic acid given in the table differ from its actual thermodynamic specific heat by an amount not exceeding 0.1-0.2% in the range where the International Temperature Scale is applicable.

Below 90° K the errors increase and, moreover, the scale adopted by the NBS differs from that used in the USSR. In this region the reliability of the data is, therefore, not so good; the discrepancies may amount to 0.5% and in the region of 10-15° K up to 5-10%. If the temperatures below 90° K are measured in degrees of the scale adopted in the USSR, it is possible to anticipate agreement between the evaluated results and those given in the table within the limits of 0.1-0.2% in the whole temperature range down to 20° K; below 20° K discrepancies may amount to 0.5%.

The close agreement between our data and the values recommended by the NBS provides benzoic acid with a characteristic of an international standard and makes it possible to compare quantitatively the measurement results obtained in various laboratories of the world.

LITERATURE CITED

1. D. C. Ginnings and G. T. Furukawa, Journ. Amer. chem. soc. 75, No. 3-4 (1953).
2. P. G. Strelkov, E. S. Itskevich, V. N. Kostryukov, G. G. Mirskaya, and B. N. Samoilov, Zhurn. fiz. khim. 28, 459 (1954).
3. A. S. Borovik-Romanov, M. P. Orlova, and P. G. Strelkov, Establishment of a Low Temperature Scale between 90.19 and 10° K by means of a Calibration Table of a Group of Standard Platinum Resistance Thermometers [in Russian] (Principal Chamber of Measures and Measuring Instruments, Moscow, 1954).
4. G. T. Furukawa, R. E. McCoskey, and G. I. King, Journ. Res. NBS 47, No. 4, 256 (1951).
5. D. W. Osborne, E. F. Westrum, and H. R. Lohr, Journ. Amer. chem. soc. 77, 2737 (1955).
6. T. Davies and L. A. K. Stavely, Trans. Faraday soc. 53, 19 (1957).
7. M. M. Popov and V. P. Kolesov, Zhurn. obshch. khim. 26, 2385 (1956).

TESTING EQUIPMENT FOR DETERMINING THE PARAMETERS OF HEAT RADIATION RECEIVERS

A. F. Mal'nev and L. S. Kremenchugskii

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 26-30, June, 1961

The main difficulty in developing testing equipment for determining parameters of heat radiation receivers consists in designing circuits which would operate in the infra-low frequency range recording signals of the order of 10^{-10} v, which are obtained from low resistance receivers. It is impossible to amplify these signals directly by means of electron tubes; moreover, the tube internal noises increase rapidly at low frequencies. Miniature step-in transformers are, therefore, used for these purposes. The object of the transformer consists in matching the equivalent noise resistance of the receiver under investigation (or the bridge in which the receiver operates) with the equivalent input noise resistance of the first tube in such a manner that the noise of the receivers could be observed in the measuring circuit over the whole operating frequency range.

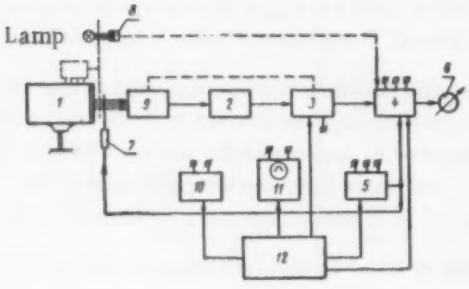


Fig. 1.

The equipment described in this article provides a relatively simple means for measuring the basic parameters of heat radiation receivers and for choosing optimum conditions of their operation.

By means of this equipment it is possible to determine the quadratic mean value of noise, the sensitivity to radiant power in modulated irradiation, the threshold sensitivity, the time constant, the spectral density of noise, and the current noises of the receiver.

Low-resistance metallic bolometers and thermocouples, as well as semiconductor bolometers and photovaristors can be tested by means of this equipment.

The equipment comprises a reference radiator 1 (Fig. 1) consisting of a cylindrical black body standard, matching transformers 2, pre-amplifier 3, main amplifier 4, audio-oscillator 5, and an output recording instrument 6 (millivoltmeter or electronic potentiometer EPP-09). Audio-oscillator 5 synchronizes the operation of the measuring channel in the range of 3 to 70 cps by feeding the vibration type modulator 7 and supplying the reference voltage to the phase detector. For operation at higher frequencies a disc type modulator is used, and the reference voltage for the phase detector is taken from photo diode 8. The tuning of the equipment, checking of its operation, and determining the parameters of receivers 9 is made by means of tube voltmeter 10 and oscilloscope 11. All the units of the equipment are mounted on a single rack. The black body standard whose output aperture faces the modulator is fixed to an optical bench which is mounted on the rack. The rack also carries a steel screened box in front of whose inspection window, cut in its upper part, the tested receiver is placed. The black body standard, which can be displaced in three mutually perpendicular directions, is adjusted in such a manner that the axis of the standard is normal to the surface of the receivers. The lower part of the box, which is partitioned off from the upper part, contains a table with a set of wire resistors, a battery and auxiliary rheostats. By their side the matching transformers are mounted in permalloy and copper screens. The pre-amplifier, which is connected by flexible short leads to the output transformer and power pack 12 is also shielded by external permalloy and internal copper screens, and is mounted on rubber shock absorbers in order to reduce the microphonic effect.

The source of the radiated energy consists of a cylindrical black body standard (Fig. 2), since it is easier to attain a uniform temperature inside a body of this shape than it would be in a spherical or tubular standard.

The quality of the standard was evaluated by the method advocated in [1]. In order to equalize the temperature along the internal surface of the standard cylinder, the nichrome wire helix was wound more closely at the ends of the cylinder. Measurements have shown that the temperature of the black body's cavity set at 450° K remains for the given system of diaphragms uniform within ± 5° K right up to the front wall of the body. The ratio of the cavity depth to the radius of the radiating aperture is then equal to 32. The black body radiation coefficient was computed

to exceed 0.99. The operating temperature of the black body is set in the range of 400-500° K, and its front wall is cooled by water. During operation the temperature of the modulator does not exceed that of the external surface of the front wall by more than 1.5° C.

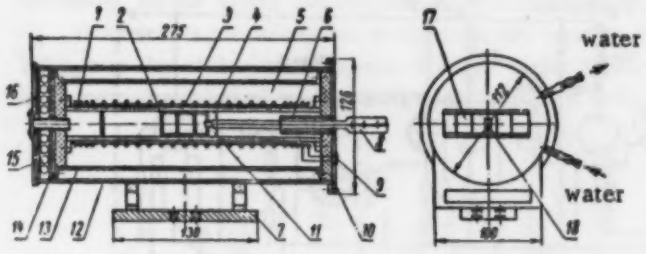


Fig. 2. 1) Internal tube; 2) diaphragm fixing tube; 3) diaphragm; 4) nichrome helix; 5) asbestos insulation; 6) insulation bush; 7) stand; 8) thermometer; 9) insulation bush; 10) heat-insulating washer; 11) insulating washer; 12) external tube; 13) second tube; 14) packing; 15) cooling coil; 16) front wall; 17) shutter; 18) special washer.

Figs. 3 and 4 show a schematic of the equipment's electrical circuit. The input unit (unit No. 1) consists of matching transformers, storage batteries, auxiliary rheostats, resistances, the pre-amplifier with T_1 tube 6Zh1Zh, which operates with a floating grid and microcurrents [2, 3]. The matching transformer Tr1 is wound on a permalloy core Sh-9 with an initial permeability of $\mu_0 = 3000$. Its primary winding is wound with 0.15 mm PÉL wire with taps at 5, 15, 35, and 70 turns for matching the low resistance of the receiver. The secondary is wound with 40000 turns of 0.03 mm PÉL wire. The transformer is tuned to the modulation frequency by means of experimentally selected capacitors C_t. Transformer Tr2 is tuned to 1000 cps and uses a permalloy Sh-09 core with its primary wound with 7 turns of 0.15 mm PÉL wire. Its secondary is divided into four sections of 500 turns each of 0.05 mm PÉL wire. The low resistance receivers are investigated either in a bridge circuit, or in a circuit with a large load resistance and the dc current in the transformer primary compensated by means of an auxiliary battery. The internal noises of the measuring device referred to the input with the primary of the transformer shorted amount to $1.1 \cdot 10^{-10}$ v at a frequency of 9 cps with an effective measuring device band width of 0.1 cps. The preamplifier gain amounts to 190, and the nonlinearity of its frequency characteristic to ± 5% in the operating range of 3-1000 cps.

Main amplifier (unit No. 2)*. The signal received from the preamplifier is amplified in tubes T_2 and T_3. In order to raise the operating stability of the main amplifier, a negative feedback is provided between these tubes, and low-frequency correction is introduced for improving the gain characteristic. The main amplifier frequency characteristic nonlinearity in the operating range of 3-1000 cps is less than ± 5%. The main selecting element of the circuit consists of a phase detector. Since the bandwidth of a phase detector is determined only by its time constant, the measuring device has a constant bandwidth throughout its operating frequency range. In order to obtain a zero (or 180°) phase difference between the signal and reference voltages in the phase detector, a phase shifter is attached to transformer Tr5. The detector reference voltage amounts to at least 10 v over the whole operating frequency range. The isolating transformers Tr3 and Tr4 have permalloy cores, and their primary and secondary windings have 20000 turns each of 0.03 mm PÉL wire. The output of the measuring device is connected to the electronic potentiometer ÉPP-09 or a millivoltmeter through a valve voltmeter (tube T_5).

RC-oscillator unit (unit No. 3). The RC-oscillator operates on the basis of a zero phase-shift feedback circuit. The operating frequency range of the main oscillator (tube T_8) amounts to 3-5000 cps. The right-hand side of tube T_9 feeds the vibration-type modulator, which uses a polarized type RP-4 relay. In order to obtain the required amplitude of oscillations, it is necessary to place load extensions over the modulator reed when the frequency is reduced from 70 cps to 3 cps. For the purpose of measuring the transfer constant of the input unit and the gain of the main amplifier, a $1:10^5$ potential divider in a steel screen is provided. The auxiliary oscillator (tube T_6) serves to feed the bolometer bridge when it operates with transformer Tr2 which is tuned to 1000 cps.

The low-frequency tube voltmeter (unit No. 4) serves for calibrating the measuring channel and for determining the receiver parameters. Its circuit is similar to that of voltmeter LV-9, but it differs from the latter by its high impedance input and its extended low-frequency range. The tube voltmeter frequency characteristic nonlinearity amounts to ± 5% in the operating range.

Oscilloscope type ÉNO-1 is intended for determining the time constant of the tested receivers, the phase angle between the reference and signal voltages, and for checking the operation of the measuring device.

* Developed by the author, together with M. P. Esel'son.

The power pack (unit No. 5) consists of an electronic stabilizer for feeding the anodes of tubes 6Zh1Zh (T_1 and T_2) and of a source for the negative bias of the oscilloscope unit. The stabilization factor of this unit amounts to 1000, and its ripple is less than 2 mv. The electronic stabilizer is fed from a 350 w ferro-resonant stabilizer.

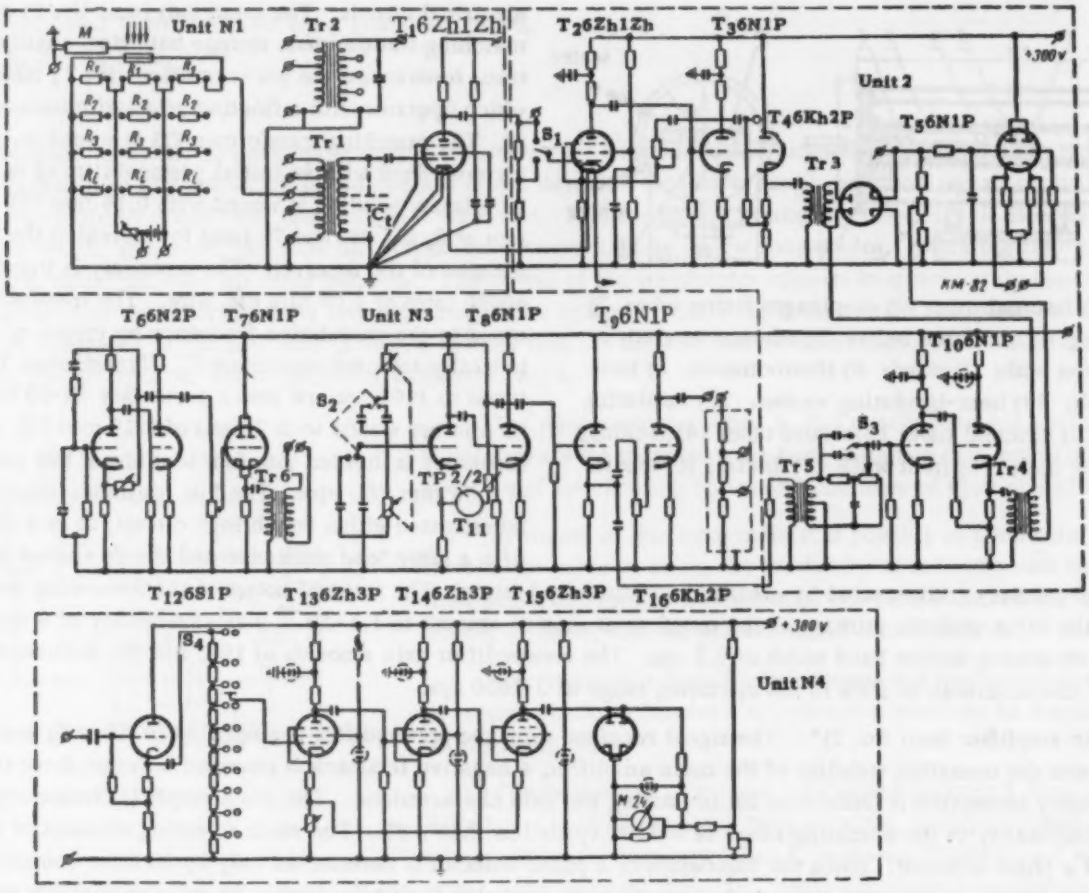


Fig. 3.

Technique in determining the basic parameters of receivers. The sensitivity to radiant power S is determined as the ratio of the effective value of the first signal harmonic produced in the receiver during irradiation to the effective value of the first harmonic of the radiation flux modulated by rectangular signals. The value W of the radiation power incident to the receiver is calculated by means of Stefan-Boltzmann's formula and multiplied by the modulation factor $\sqrt{2}/\pi$. The distance between the black body and the tested receiver should be not less than 20 cm, thus providing a sufficiently good agreement between the measured and calculated power. The effective value of signal V which arises in the receiver during irradiation can be calculated if the gain of the equipment and output instrument readings are known. The required sensitivity will then be S = V/W.

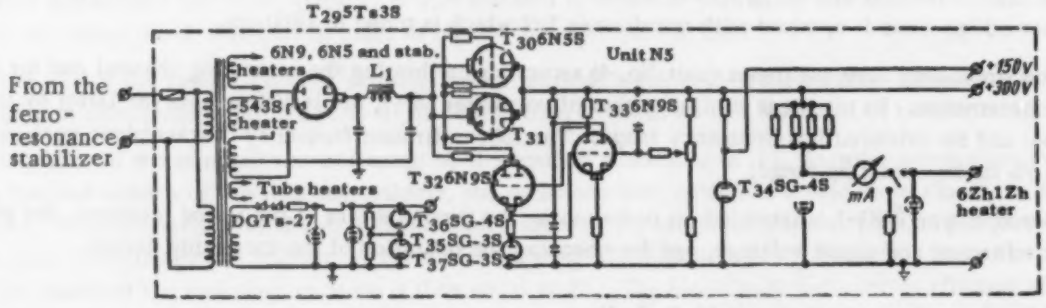


Fig. 4.

It is essential to determine the transfer factor of the input unit. Below we suggest a method of determining the transfer factor of the input unit when testing bolometers (Fig. 5). The bridge circuit (Fig. 5a) of the irradiated bolometer can be represented as shown in Fig. 5b. The transmission of the signal which arises in an irradiated bolometer and is represented by the voltage of an equivalent generator $\Delta R_b I$ (where I is the current flowing through the bolometer) and the tuning of the transformer to the modulation frequency obviously depend on the shunting effect of the bridge supply source and the receiver's time constant, which is determined by the receiver equivalent capacitance C_e. Hence, it is recommended to measure the transfer constant, determined as the ratio of the preamplifier output voltage to the equivalent generator voltage, under operating conditions as shown in Fig. 5c. Transfer constant measurements made according to the circuit shown in Fig. 5d may in many cases lead to considerable errors.

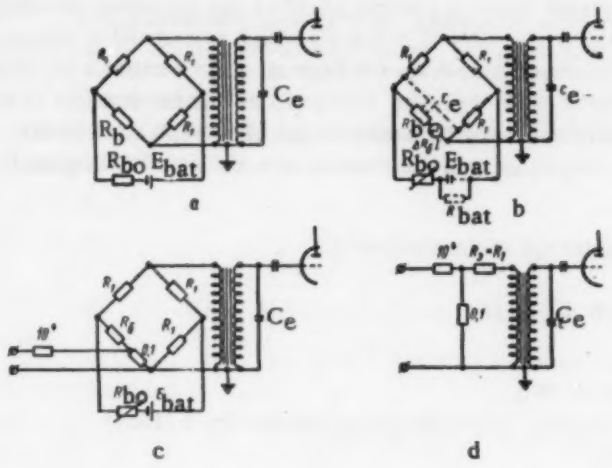


Fig. 5.

The quadratic mean value $\sqrt{\varepsilon^2}$ of the receiver noise can be determined in low resistance bolometers by two methods. The first method consists in comparing the tested bolometer noise with that of a wire resistor equal to it in size. At first the noise level of the tested bolometer bridge is measured under working conditions, and then the noise level of the wire resistor which replaces the bolometer and is equal to it in size. Such measurements do not require checking of the input unit transfer constant, and in them the measuring circuit only serves as a sensitive indicator. However, it should be remembered that in these measurements the temperature of the bolometer with the current passing through it is 30-100° C above that of the wire resistor, and that this condition may lead to errors amounting to 10%. Thus, the quadratic mean value of the receiver noise can be determined in units of its thermal noise, i.e. it is possible to evaluate the ratio of the receiver noise to that of a wire resistor equal to it in size, and the absolute value of the noise can be calculated from the well-known formula of Nyquist. The second method in which a circuit with a large load resistance R_1 is used provides a more accurate determination of a low-resistance bolometer noise either by direct measurement, or by comparing it with the noise of a wire resistor equal in size to the bolometer. The noise of thermocouples is measured by connecting them directly to the appropriate tappings on the transformer primary winding. In all the noise and sensitivity measurements of bolometers, bolometer bridges and thermocouples they are connected to the primary transformer winding tapping which provides the maximum transfer constant at a given frequency. The noise level of semiconductor high-resistance bolometers is measured by connecting them directly to the first tube. The tube anode and heaters are then fed from storage batteries. In order to obtain an accurate measurement of the receiver noise, it is necessary to take into account the internal noise of the measuring device. The noise characteristic recorded on an electronic potentiometer ÉPP-09 is averaged over a time t. The relative error in determining the quadratic mean value of the noise is then proportional to $t^{-1/2}$.

If the receiver noise is compared to that of a wire resistor equal in size to the receiver, a pointer output instrument may be used, taking as a measure of comparison the difference between the maximum and minimum deflections of the pointer during 2-3 minutes.

The receiver's threshold sensitivity Q_{min} is determined as the radiation power which provides a receiver signal equal to the quadratic mean value of noise. In practice the threshold sensitivity is obtained by dividing the quadratic mean value of the receiver noise by its sensitivity to radiant power. The relative error in determining threshold sensitivity does not exceed ± 30%.

The receiver time constant t can be determined as the time required after a sudden irradiation of the receiver for the signal to attain 63% of its constant value. The receiver time constant is determined in this manner when it is irradiated by rectangular pulses. The modulation frequency and time constant should then be related approximately by the ratio $1/f = (6-8)\tau$.

The receiver time constant can also be determined from its frequency characteristic by the well-known technique. The frequency characteristic of bolometers can be rapidly obtained if the bridge is fed by 1000 cps (the

matching transformer Tr2 is then used) and the output signal is measured with a tube voltmeter. The frequency characteristic thus obtained is then used to determine the time constant from the formula $\tau = 1/2f_0$, where f_0 is the frequency at which the signal attains 0.465 of its zero frequency value. The time constant can be determined by measuring the sensitivity to radiant power at two frequencies providing the frequency characteristic follows the law of $[1+(2\pi f\tau)^2]^{-1/2}$. The relative error in thus determining the time constant is ± 10%.

The analysis of the spectral distribution of noise and noise currents is made at different frequencies and different current values.

CONCLUSIONS

The equipment for determining the parameters of receivers makes it possible to select the optimum operating conditions for bolometers, i.e. to find the values of the operating current and frequency which correspond to the receiver's minimum threshold sensitivity. The use of a vibration-type modulator fed from an audio oscillator provides rapid measurements of receiver parameters in the basic range of 3-70 cps. The utilization of a phase detector in the measuring device provides a uniform bandwidth over the whole operating frequency range. The evaluation of the transfer constant under working conditions for each receiver connected to a transformer does not require additional time, but it raises the reliability of measurements.

V. I. Mel'nikov participated in the production and adjustment of the equipment.

LITERATURE CITED

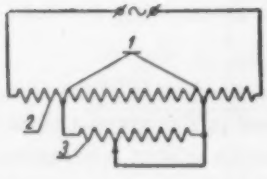
1. De Vos, Physica 20, No. 10, 669 (1954).
2. I. U. White and M. D. Liston, J. O. S. A., 40, No. 2, 93 (1950).
3. V. I. Dianov-Klokov, A. D. Stakhovskii, and L. A. Osterman, Izmeritel'naya tekhnika, No. 2 (1957).
4. R. M. Milton, Chemical Reviews, 39, No. 3, 419 (1946).
5. M. N. Markov, Optika i spektroskopiya, v. 3, No. 2 (1957).

SIMPLE METHOD OF EQUALIZING THE TEMPERATURE FIELD OF TUBULAR RESISTANCE FURNACES

B. K. Bragin

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 30-31, June, 1961

The tubular type laboratory electric furnaces with tape or wire heaters are widely used in research work and are often required to have a strictly uniform and extensive temperature field. Such requirements are specified for furnaces used as black-body radiators or for heat treatment of sample materials and their mechanical testing, for studying chemical reactions, calibrating and checking thermometers, etc.



1) Uniform temperature field; 2) furnace heater; 3) shunt.

Several methods of equalizing the temperature field of tubular furnaces are used, namely, improved lagging of the furnace ends, unequal pitch of the heater winding, the use of tapes and wires of variable cross sections, separate supplies to several independent sections of the heater, fitting of additional heaters at the ends of the furnace, etc. The majority of these methods is complicated and only provides a uniform temperature field for certain operating conditions of the furnace. In changing over to another operating condition the temperature field is distorted and the furnace requires either complete or partial reconstruction.

We have applied a simple method of equalizing the temperature field over a considerable part of the furnace's working space by shunting an appropriate part

of the heater with a variable resistor (or a fixed resistor for constant operting conditions). The shunt can consist of a rheostat with a slider.

The method of connecting the shunt is shown in the figure attached.

The shunt reduces the current density in the middle part of the heater where the temperature is at its maximum. At the same time, the current density in the end portions of the heater is slightly increased. By varying the shunt resistance it is possible to obtain the required temperature distribution over the shunted portion for any operating condition of the furnace.

The power loss in the shunt depends on the design characteristics of the furnace, on its lagging, and conditions of operation, and may reach 10% of the total power used by the furnace.

If it is necessary to operate the furnace at several temperatures, the required position of the rheostat (shunt) slider can be determined in advance and marked off.

The above method has been used by us in furnaces for calibrating thermocouples and for their homogenizing annealing. The uniform temperature field of these furnaces was extended after connecting the shunt by a factor slightly exceeding 1.5.

ELECTRICAL MEASUREMENTS

NEW MODEL OF A HIGH-RESISTANCE SIX-DECADE POTENTIOMETER

T. B. Rozhdestvenskaya, D. I. Zorin, and A. M. Brodskii

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 31-36, June, 1961

GOST (All-Union State Standard) 9245-59 specifies, in response to the requirements of our national economy, grade 0.005 potentiometers. The most accurate potentiometers produced to date by our instrument-making plants only meet grade 0.015 requirements. The top measuring limit of existing dc potentiometers does not exceed (or approaches) 2 v, although in many instances the measurement of much higher emfs is required.

Table 1 provides the basic information on certain most accurate high-resistance potentiometers.

The new high-resistance potentiometer KRV-8 developed by us* fills the existing deficiency in this sphere.

In designing the KRV-8 potentiometer we aimed at obtaining an instrument of a higher grade of precision than the existing instruments. This determined the choice of a six-decade circuit. The most accurate modern high-resistance potentiometers are made with six decades, thus providing readings with an error of 0.001%. However, in the majority of cases such high reading accuracy is superfluous, and sometimes can even deceive the operator, since the potentiometer error is much greater than the above value, for instance, in grade 0.015 potentiometers.

Potentiometer circuits with replacement decades have proved to be satisfactory in practice, and although the existence of additional decades at first sight seems to complicate the construction of the potentiometer, the simplicity of the circuit and its setting, as well as the ease of checking and introducing corrections during the operation of the potentiometer, completely outweigh the complication introduced in the circuit [1].

The new potentiometer model is based on a circuit with four replacement decades. The values of the various decade coils are given in the schematic of Fig. 1, in which the value of the decade calibrations such as × 0.1 v, × 0.001 v, etc. is marked on the range switch which is shown in position × 1.

The main peculiarity of this potentiometer consists in the existence of two limits of measurement (1.9 and 19 v). In switching over to the higher measuring limit the operating current of the potentiometer is raised by a factor of 10 (from 0.1 to 1 ma) without changing the potentiometer resistance. For this purpose a battery with a nominal voltage of 20 v is used. The changing over to the other battery is made by means of switch S_1. The operating current is adjusted by three groups of resistors in steps of 0.2 ohm which provide variations in the potentiometer operating current of 0.001%.

The operating current is accurately set against a standard cell by means of adjusting decades in steps of 0.001% of the basic resistance value. The operating current is set by means of three adjusting decades only; moreover, only two of them are used for each selected measuring range.

When working in the range of × 1, the adjusting resistance consists of 11 resistors of the first decade 9 × 1 and 10 × 0.1 ohm. The adjusting resistance can then be set between 10190.0 and 10180.0 ohm, thus making it possible to compensate with a current of 0.1 ma the variations of the standard cell emf in the range of 1.01800 to 1.01900 v. When working in the range of × 10, the adjusting resistance consists of the first two resistors of the first decade, which include the adjusting decades of 10 × 0.1 and 10 × 0.01 ohm. The maximum value of the adjusting resistance in this case is equal to 1019.10 ohm and the minimum to 1018.00 ohm.

The potentiometer measuring resistors are wound with manganin wire. For the first three decades resistances with temperature coefficients which do not differ from each other by more than 0.001%/1° C were selected.

The thermal emf generated in the potentiometer measuring circuit with stationary wipers does not exceed 0.2 μv. The wiring and contact resistances of switches provide with an operating current of 0.1 ma a constant voltage

* A. A. Skragan and É. É. Ludé, members of the VNIIM (All-Union Scientific Research Institute of Metrology) design bureau participated in the development of this potentiometer.

drop across terminals E_x of 0.8 μv for a zero setting of the potentiometer. Variations in the zero voltage drop do not exceed 0.1 μv.

TABLE 1.

Potentiometer type; manufacturing plant	Number of measuring decades	Measuring limits, v	Calibration of the smallest measuring decade, μv	Resistance of the measuring circuit, ohm	Operating current, ma	Error in setting the operating current, %	Maximum permissible error when all the decades are used, %	Circuit
Wolf	5	10.9999 1.09999 0.109999	100 10 1	10999 10999 10999	1 0.1 0.01	0.01 0.001 0.0001		Double series connected (3 replacement decades)
PV-6 "Étalon"	5	1.9	10	19000	0.1	0.001	0.015	The same
PV-7 "Étalon"	6	1.9	1	19000	0.1	0.001	0.015	Double series connected (with replacement decades)
R-300, ZIP (modernized PPTV-1)	5	1.9	10	19000	0.1	0.005	0.015	Double series connected (3 replacement decades)
PPTV-1, ZIP	5	1.2	10	12000	0.1	0.01	0.03	
R-375, ZIP	6	1.2	1	12000	0.1	0.005	0.015	3 replacement decades, 2 cascade decades
R-307, ZIP (modernized R-375)	6	1.9	1	19000	0.1		0.015	The same
KRV-8, "Étalon"	6	1.9 19	1 10	19000	0.1 1	0.001		Double series connected (4 replacement decades)

In testing the potentiometer its errors were determined both at room temperature and in the range of 20 to 30° C. The errors were determined by checking each component in the manner used for testing reference potentiometers. After each component had been checked the readings of the new potentiometer were compared with those of a VNIIM reference potentiometer, whose components had also been previously checked one by one. The method of checking one component at a time in six-decade potentiometers is described in detail in [2].

The existence of an additional measurement range in the new potentiometer made its checking slightly more complicated owing to the necessity of determining the ratio of two setting resistances. This operation was carried out by means of an auxiliary potentiometer whose operating current was set by one standard cell when the tested potentiometer was switched to range × 1, and by means of 10 series connected 1st grade standard cells when the potentiometer was switched to range × 10, thus raising the reference testing voltage by a factor of 10. This method of determining the ratio leaves the setting resistance and the measuring resistance of the reference potentiometer unchanged, and does not actually require any corrections to be applied to the reference potentiometer.

Table 2 shows the basic test results* of the first three models of potentiometer KRV-8.

*E. K. Vesso-Ado carried out the experimental investigation of the potentiometer.

Temperature variations were measured on the × 1 range at a minimum setting of the first decade which is the worst possible condition.

The limiting error in volts of the KRV-8 potentiometer can be expressed by the formula

$$\delta = \pm (0{,}5 \cdot 10^{-4}\, U + 0{,}8\, \Delta U), \tag{1}$$

where U is a given potentiometer reading; ΔU is the calibration of the smallest measuring decade, v.

The data given in Table 2 shows that the newly developed potentiometer exceeds in its accuracy the group A [3] potentiometers now produced by our industry and approaches the highest grade potentiometers specified by GOST 9245-59.

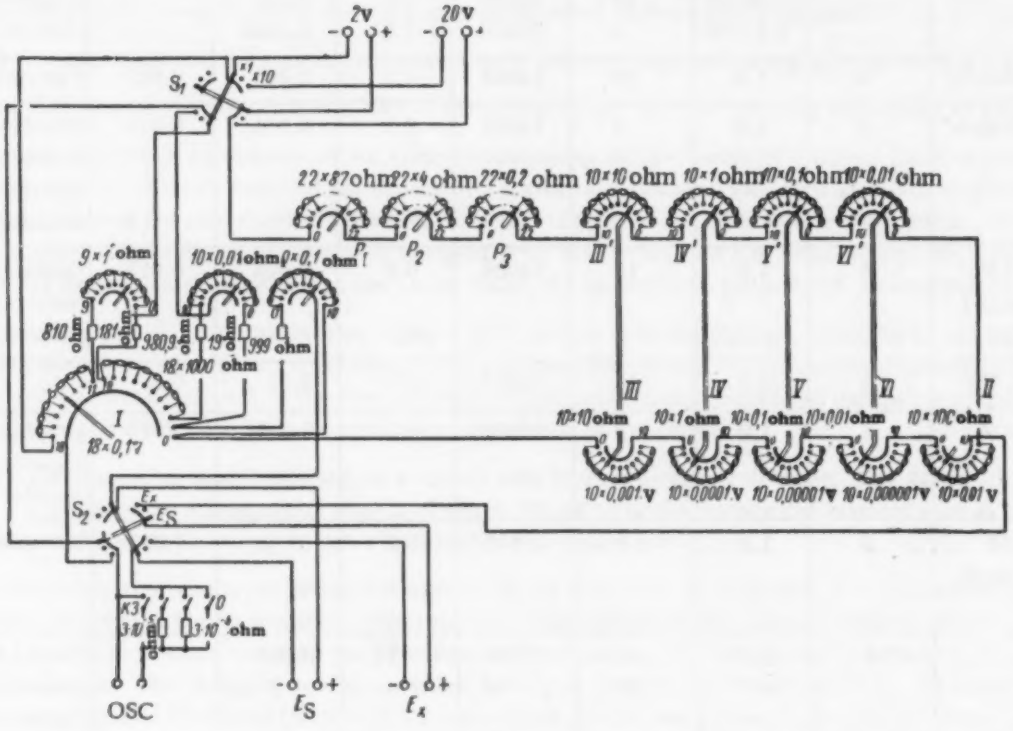


Fig. 1.

The development work carried out according to special technical conditions of a high precision dc potentiometer model revealed the manner in which a grade 0.005 potentiometer could be produced by our industry.

The main discrepancies between the new model and the requirements specified by the GOST for grade 0.005 potentiometers consist of an insufficient smoothness in adjusting the operating current (0.001% instead of 0.0005%), and the large value of the second term in the error formula (1) as compared with 0.5 ΔU provided by the GOST.

It is not difficult to raise the smoothness in controlling the operating current, which can be achieved simply by adding a fourth adjusting decade with a minimum calibration of 0.1 ohm.

Far greater constructional and technological difficulties are encountered in reducing the factors which determine the value of the second term in the potentiometer error formula. The limiting value of this term as shown in the formula is determined by the voltage drop across the contact resistance of brushes in each of the replacement measuring decades, and by the drop in the wiring connecting the decades. The GOST requirements can be met in the six-decade potentiometers with a double series connected circuit providing:

$$I_p (nr + r_n) < 0{,}5 \Delta U, \tag{2}$$

where I_p is the potentiometer operating current; $\underline{n}$ is the number of decades in the measuring circuit; r_n is the resistance of the wired connections; $\underline{r}$ is the contact resistance of a single decade switch; ΔU is the calibration of the smallest decade, v.

TABLE 2.

Sample No.	Maximum error of the first decade in % of a given reading	Maximum variation in the readings of the first decade in the temperature range, %/1° C		Error in the potentiometer multiplier, %	Zero value of the potentiometer emf, v
		20-26° C	24-30° C		
1	+ 0.002	+ 0.0007	+ 0.0003	0	$0.8 \cdot 10^{-6}$
2	+ 0.002	+ 0.0015	+ 0.0008	−0.001	$0.8 \cdot 10^{-6}$
3	+ 0.004	–	–	−0.003	$0.8 \cdot 10^{-6}$

In the potentiometer model under consideration the left-hand side of inequality (2) is equal to 0.1 μv for an operating current of 0.1 ma. The greater part of this quantity is due to the contact resistances of the decade switches (whose maximum value for various switches lies in the range of 0.0005 to 0.001 ohm).

One of the circuit solutions applied in practice consists in using in addition to the double series circuit also a cascade circuit in which the second decade is shunted by the sixth. Since the current branching off to the sixth decade becomes a small fraction of the operating current, it is then possible in practice to neglect the voltage drop across the contact of the shunting decade.

Potentiometer PV-4 was constructed on this principle [2]. The same principle was used in designing potentiometer R-375. It should be noted, however, that such a circuit solution only eliminates the effect of one contact resistance out of four, thus providing a small advantage. The zero voltage across the first model of potentiometer PV-4 amounted to 0.8 μv. Another method consisting in raising the number of resistors, for instance up to 100 [4], operated from one switch, (merging of two decades) is not satisfactory, since it leads to an increased size of the instrument and complicates the construction of a decade switch.

TABLE 3.

Potentiometer No	α, %/1°C	t_{max}, deg
1	from −0,0001 to +0,0003	18–20
2	" +0,0003 " +0,0007	23–26
3	" −0,0003 " +0,0006	12–16

In addition to the above two methods of lowering the zero voltage drop, it is also possible to use an artificial means of eliminating the unchanging portion of the voltage drop by including the zero resistance in the first resistor of the sixth decade. In this case the reading of the sixth decade begins with unity. With such an artificial elimination of the zero resistance, the second term of the error formula is determined only by the variations in the initial voltage drop. It is obvious that the above method can only be adopted with a sufficiently stable zero resistance which depends both on the design and construction of the potentiometer and on the conditions of its use (timely and correct cleaning and lubrication of contacts).

With respect to the additional error caused by temperature variations, the new potentiometer model meets the requirements of grade 0.005 potentiometers only by overcoming considerable organizational and technical difficulties. These difficulties are due to the necessity of making the first and second decade manganin resistors meet the following conditions:

the resistors forming the adjusting and measuring resistances must have approximately the same temperature coefficients in order to bring the temperature error of the potentiometer within the required tolerance;

the temperature for the maximum resistance must be in the working temperature range, i.e., about 20-23° C.

Table 3 gives the values of α for the resistors of the first decade.

The 100 ohm resistors (second decade) were found to have positive temperature coefficients only. However, certain discrepancies between the values of resistors in the first and second decades cannot affect substantially the temperature coefficient of the potentiometer as a whole.

If the stability with time and temperature coefficient requirements for the resistors of the first two decades are taken into consideration, it becomes obvious how difficult commercial production of grade 0.005 potentiometers will be.

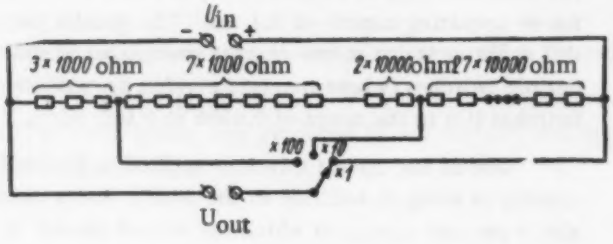


Fig. 2.

Extending the potentiometer range. In order to extend the voltage range of the potentiometer, we developed a potential divider DN-9 (Fig. 2) with a large input resistance (300000 ohm). The potential divider has three ratios* K_n = 100, 10, and 1, and its ratio error does not exceed 0.005%.

The potential divider resistors (of 10000 ohm each) were selected on the same principle as those of the potentiometer, with the only difference that their temperature coefficients were found to be considerably larger. However, owing to the small differences between these values, the total temperature error for the divider attained the same order of magnitude as that of the potentiometer.

Fig. 3 shows the graphs for the relative variation of resistance Δr in the potential divider sections with respect to temperature, and Fig. 4 the relation between the divider ratios and temperature. It will be seen from the graphs that the divider ratio errors do not exceed ± 0.005% in the range of 18-28° C, and that even with fairly large (but equal in magnitude and of the same sign) temperature coefficients of resistors in various sections of the divider (Fig. 3) the effect of temperature on the divider ratios is small (Fig. 4).

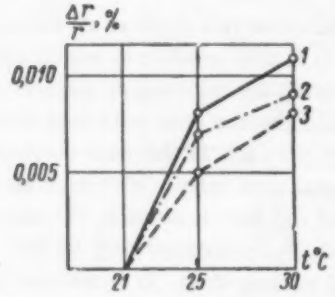


Fig. 3. 1) For r = 300000 ohm (total divider resistance); 2) for r = 30000 ohm (resistance of a section); 3) for r = 3000 ohm (resistance of a section).

Auxiliary Devices and protection of the potentiometer circuit. Raising the accuracy of dc compensation measurements cannot be limited to the production of a high precision potentiometer and potential divider. In order to be able to set the operating current with an error not exceeding 0.001% it is necessary to use a grade 1 standard cell, whose emf is determined by means of a temperature formula with an error not exceeding 10 μv.

The supply sources of the potentiometer operating circuit must provide a current whose variations during measurements do not exceed 0.0005%. It should be noted that such a stringent requirement with respect to the stability of the source of supplies is more easily fulfilled in a high-resistance potentiometer. However, this advantageous property of a high-resistance potentiometer is counterbalanced to some extent by more stringent requirements with respect to leakage currents through the insulation of the measuring circuit.

In fact, in order to keep the error due to the leakage current below 0.0005%, the potentiometer insulation resistance must exceed 10^9 ohm for an operating circuit resistance of 20000 ohm. In order to maintain this insulation and protect the potentiometer from interference, it is enclosed in a screen [5]. The insulation resistance is measured between the compensator measuring circuit and the screen. The insulation requirements of a potential divider (which is also screened) are even more stringent and amount to $6 \cdot 10^{10}$ ohm. Polished ebonite is used for insulating the potentiometer and its components are made of compressed powder K-21-22. The potential divider is insulated with polystyrene.

For measuring emfs or voltages with an error not exceeding 0.001% it is necessary to have a null indicator with a sensitivity not less than 0.5 μv/div for measuring emfs smaller than 0.1 v.

Maximum current sensitivity for a null indicator is required when potentiometers with a high-resistance potential divider are used. In this case a null indicator current sensitivity of the order of 10^{-10} amp/mm is required. Such a sensitivity can be provided by stationary mirror galvanometers.

* Multiplier × 1 is provided for testing converters with a constant load.

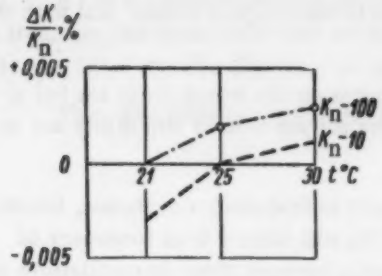


Fig. 4.

In the new potentiometer model we used for a null indicator a photocompensation microvoltammeter F116/2. When it is used as a microammeter in the 0.015 μa range its minimum calibration amounts to $2 \cdot 10^{-10}$ amp, which is satisfactory even for the worst possible operating conditions with a high-resistance potential divider. With an external circuit resistance not less than $2 \cdot 10^3$ ohm, the instrument's settling time does not exceed 6 sec. The instrument is made in a portable form with a pointer indicator, and despite the fact that it must be used on a shock absorbing stand, its erection is much simpler than that of a stationary mirror galvanometer of the same sensitivity. A substantial advantage of this instrument as compared with normal mirror galvanometers consists in its sensitivity and settling time being less affected by the measuring circuit resistance variations over wide limits, which is of great advantage for the operation of a potentiometer.

The above work shows the possibility of producing a grade 0.005 potentiometer, which is now being pursued by the VNIIM.

LITERATURE CITED

1. K. P. Shirokov, Works of the VNIIM [in Russian], No. 24/84 (Mashgiz, Moscow, 1954).
2. K. P. Shirokov, Works of the VNIIM [in Russian], No. 6/66 (1949).
3. Instruction of the Committee of Standards, Measures, and Measuring Instruments, 189-54.
4. Scientific Instr. 32, No. 1 (1955).
5. Krukovskii, Annales de l'Academie des Science Technique a Varsovie, t. 1, p. 123, (1935).

OBTAINING A GIVEN PHASE SHIFT BETWEEN VOLTAGES BY THE BEATING METHOD

E. D. Koltik

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 36-38, June, 1961

Among the various means of producing voltages mutually displaced in phase, the method based on beating effects plays an important part. The generators based on this principle [1, 2] contain in their fixed frequency channel a time modulator, which normally consists of different types of phase shifters with a range of 0 to 360°. Thus, the accuracy of evaluating the phase difference angle between the output voltages of such a generator depends in the long run on the precision of the phase shifter calibrations and their stability in time. Capacitative, inductive, and other phase shifters do not provide a sufficiently accurate setting of the phase difference between the generator output voltages.

The method which we have developed [3] for setting phase differences between the output voltages is based on strictly determined physical relations and does not require a calibrated phase shifter, thus providing far greater accuracy.

It is known that one of the properties of the Lissajous figures consists in their passing through 2 n characteristic positions when the phase of the lower-frequency signal varies by 360°. This property is taken as the basis for precision phase difference measurements.

The circuit for generating voltages with a mutual phase difference is shown in Fig. 1. Oscillations of a frequency of nf_0 are fed from a fixed frequency oscillator 1 to a frequency divider 2 with a scaling factor n and to oscilloscope 4. The other oscilloscope input is fed from a phase shifter 3. Mixers 5 and 7 are supplied with signals of

frequency f_0 from the input and output of phase shifter 3, which varies the phase in the range of 0-360° and with the voltage from an auxiliary oscillator 6 of frequency f.

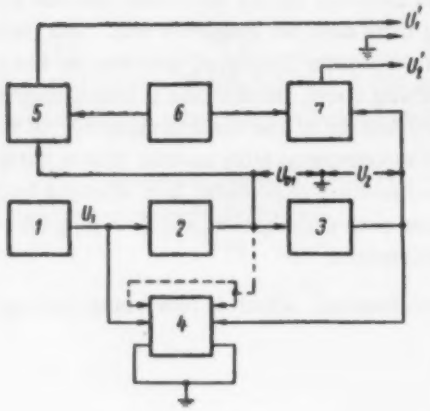


Fig. 1.

The beat frequencies which appear on the mixer loads are fed to filters and output amplifiers (the latter for the sake of simplicity are not shown in Fig. 1).

The phase relations are preserved in frequency conversion, hence, the oscillator output voltages U_1' and U_2' will have a beat frequency of f_0-f and will have the same phase angle between them as oscillations of frequency f_0.

The phase difference φ between voltages U_{01} and U_2 at the input and output of the phase shifter corresponds to the phase difference at the output of the generator, and is conveniently evaluated by fixing the instant of the Lissajous figures "degeneration" into a curve, whose shape resembles a sine wave which we shall call an open Lissajous figure.

The zero phase difference between voltages U_{01} and U_2 is set in the following manner:

With the frequency ratio of voltages U_{01} and U_1 equal to 1/n, the initial open Lissajous figure is produced on the screen of a cathode-ray tube by means of an additional phase shifter placed in the frequency divider unit. Voltages U_{01} and U_2 are then fed to the oscilloscope and a zero phase difference between them is set with an error of ± 2° by adjusting the 0-360° phase shifter until the ellipse seen on the screen is reduced to a straight line. By observing on the oscilloscope screen the Lissajous figure for a frequency ratio of 1/n, it will be seen that this figure differs from the initial one owing to the error in setting the zero phase difference. This error may be eliminated by a small adjustment of phase shifter 3, which converts the observed image into an open Lissajous figure.

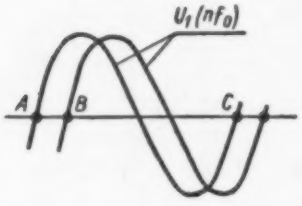


Fig. 2.

When the zero position of the phase shifter is set, it is easy to obtain any required value for the phase difference between voltages U_{01} and U_2 (U_1' and U_2' respectively) in intervals of 360°/2n, since the Lissajous figure "degenerates" 2 n times when the lower-frequency phase is shifted through 360°. By connecting in series with the main phase shifter an additional calibrated one with a range of ± 360°/2 n, it becomes possible to set any required phase angle within each interval. For measurements which do not require high precision the phase difference may be estimated from the geometrical relationship of the Lissajous figures.

The error in obtaining phase differences between voltages U_{01} and U_2 is mainly determined by the inaccuracies in superposing lines observed on the oscilloscope screen. In fact, if we denote by T_1 the oscillation period of voltage U_1 and by T_2 that of voltage U_2, we obtain

$$T_1 = \frac{T_2}{n}.$$

Considering that segment AC (Fig. 2) corresponds to T_1, and that AB corresponds to error $2\Delta\varphi$ due to the inaccuracy in superposing the lines, we shall obtain the following relation:

$$\frac{AC}{T_1} = \frac{AB}{2\Delta\varphi};$$

whence

$$\Delta\varphi = \frac{T_2}{2n} \cdot \frac{AB}{AC} = \frac{360^\circ}{2n} \cdot \frac{AB}{AC}.$$

It can be considered that an observer estimates the instant the lines coincide with an accuracy of the width of a line, i.e. the worst case with an error of ± 1 mm. Whereas the length of segment AC is determined by the gain of the amplifier and the diameter of the oscilloscope screen, and can be increased up to 30-50 mm.

Thus, the error in setting the phase signals is in the main determined by the scaling factor n, hence

$$\Delta\varphi \approx \frac{7-12}{2n}.$$

The choice of the phase shifter operating frequency is determined by the possibility of tuning out a signal of frequency f_0-f at the output of the mixer. Thus, in one of the working circuits produced by us for output voltages in the range of 20 cps-20 kc, the phase shifter operating frequency was fixed at 200 kc and the frequency range of the auxiliary oscillator correspondingly at 180-200 kc.

In this case the circuit shown in Fig. 1 was slightly modified, namely, the phase shifter was supplied with a frequency of 200 kc from a crystal-stabilized oscillator, and for obtaining a frequency of nf_0 a frequency multiplier with a multiplication factor of $n = 36$ was used.

In a general case the choice of n is determined by the properties of the cathode-ray tube, since at frequencies of the order of hundreds of megacycles additional phase shifts due to transit errors and potential variations are possible. Another important factor which determines the choice of n is the difficulty of obtaining highly phase-stable Lissajous figures which depend to a great extent on the stability of the voltage supplies. In particular, the heaters should be supplied with a direct current stabilized up to ±(0.2-0.5)%. The stability of the anode and grid voltage supplies should be maintained with an error not exceeding ± 0.05%.

It was found in practice that in order to ensure a high phase stability of Lissajous figures it is also necessary to reduce as far as possible stray amplitude modulation produced by noise, ripple, and combination frequencies in the channels, since stray amplitude modulation can produce phase modulation of the compared oscillations, thus leading to the "creeping" of the phase zero and to "blurring" of the image on the cathode-ray tube.

Special attention should be paid to the identity of amplifying channels phase characteristics, since any discrepancy may lead to considerable phase errors in setting the zero phase difference between the output voltages.

CONCLUSIONS

The tests carried out by us have shown that it is possible with the above beating method circuit to set a given phase difference between voltages with an error not exceeding 0.1-0.3°, providing the described precautionary measures are observed. The above method can find wide application in producing reference phase-difference generators used for checking electronic phasemeters.

The majority of phasemeters intended for measuring phase differences between two voltages have a linear scale and incorporate devices for setting the zero value of the phase. In such meters only the linearity of their scale need be checked. This circumstance makes considerably less stringent the requirements for the identity of the phase-difference generator amplifying channels, since the setting of the zero value of the phase can be made by means of the tested phasemeter.

If the output of one of the channels is fitted with a calibrated potential divider it also becomes possible to use the device for measuring voltages by the compensation method.

Phase-difference generators with a continuous adjustment of the phase angle in a given frequency range can be used widely not only for testing purposes but also for measuring phase characteristics of amplifiers, filters, and other radio equipment, as well as for adjusting components of tracking systems, computers, and other automatic equipment.

LITERATURE CITED

1. P. A. Matveev, Universal audio-frequency oscillator for compensation measurements, IÉST, 4, 43 (1936).
2. G. B. Madella, A Two Phase Beat-Frequency Oscillator for Audio Frequencies, Alta Frequenza, 12, 5, 248 (1943).
3. E. D. Koltik, Calibrator of the phase difference between two signal voltages. Author's Certificate No. 133924, effective from March 24, 1960.

MEASUREMENTS OF WATTLESS POWER AND THE POWER FACTOR WITH A NONSINUSOIDAL CURRENT AND VOLTAGE

P. B. Usatin

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 38-41, June, 1961

The increasing use in power engineering of various types of rectifiers and converters, the electrification of transport and the increasing number of nonlinear electrical circuits raise before electrical measuring technology the problem of measuring accurately the power in electrical circuits with a nonsinusoidal current and voltage.

The power is successfully measured with electrodynamic or thermoelectric wattmeters designed for a wide frequency range. In order to measure the wattless power and the power factor it is first of all necessary to determine the object of these measurements. At present there does not exist a generally accepted definition of these quantities for nonsinusoidal currents and voltages.

If a linear electrical circuit is fed with a nonsinusoidal voltage u (t), the current i (t) in this circuit will also be nonsinusoidal. In a nonlinear circuit the current will be distorted even if the voltage fed to it is sinusoidal. For these circuits the instantaneous, active and full power are determined in the same manner as for linear circuits:

$$s(t)=u(t)\,i(t); \tag{1}$$

$$P=\frac{1}{T}\int_0^T u(t)\,i(t)\,dt; \tag{2}$$

$$S=UI, \tag{3}$$

where U and I are the effective values of the voltage and current.

Various definitions have been suggested for the wattless power and the power factor in circuits with nonsinusoidal currents and voltages.

Budeanu [1 and 2] has suggested that the wattless power should be considered as the sum of reactive powers formed by voltages and currents of similar harmonics. This definition cannot be considered completely satisfactory for the following reasons:

a) if, for instance, a nonsinusoidal voltage without a direct component is applied to a capacitance (an ideal capacitor), it is natural to consider that the total power in the circuit is reactive. However, according to Budeanu the wattless power in this instance will be smaller than the total power. For circuits containing capacitance, inductance, or mutual inductance, and for nonlinear circuits, we have:

$$P^2+Q^2<S^2,$$

where Q is the wattless power.

In order to account for this difference the distortion power was introduced

$$T=\sqrt{S^2-P^2-Q^2},$$

whose physical meaning is not clear;

b) due to the creation of the distortion power the definition of the power factor becomes uncertain; some authors define it as the ratio of P to S, and others as the ratio of P to $\sqrt{P^2+Q^2}$;

c) in order to compute or measure wattless power according to Budeanu it is first of all necessary to expand the current and voltage periodic functions into their harmonic components, thus introducing considerable complications to the problem;

d) in deducing the above definition it was assumed that there is complete analogy between the active and wattless powers. Since the active power is a mean value it is natural to assume for it a simple summation of harmonics. The wattless power (for each harmonic) consists of the amplitude of harmonic oscillation (of a double frequency); there are no reasons to add the amplitudes of various oscillations for a wattless power of a complex former. It would be more natural to assume the law of quadrature summation for the amplitudes of various harmonic components.

It is more accurate to adopt the suggestion made by Fryse [3 and 4] of defining the wattless power in an electrical circuit with a current and voltage of any waveform as the square root of the difference of the squares of the total and active powers

$$Q=\sqrt{S^2-P^2}. \tag{4}$$

This definition, which is applicable both to linear and nonlinear circuits and does not require expansion into harmonic components with their subsequent summation, was taken by the author of this article for the basis of his method of measuring wattless power and the power factor.

In a general case an alternating current or voltage can be represented sufficiently fully as periodic functions of time not only by a Fourier series expansion, but also by means of certain general characteristics. Two of them are similar to the characteristics of sinusoidal variables, namely the period (or frequency) and their quadratic mean (effective) value. The third parameter must represent the shape of the curve. The latter is characterized by the so-called form function, which is a dimensionless function of the type $F(t + t_0)$. The fourth parameter t_0 determines the initial value of the form function $F_{t=0} = F(t_0)$.

Periodic curves which have the same shape (i.e. which can be superposed by an appropriate shifting along the time axis and suitable selection of the scale) are represented by the same form function F with arguments which only differ by the constant term t_0.

By expressing the time in fractions of a period, introducing the factor of 2π into the argument of function F in order to obtain similarity with sinusoidal variables, and denoting

$$\frac{2\pi}{T}=\omega; \quad \omega t_0=\varphi_0,$$

where ω and T are the frequency and period of the current, it becomes possible to represent the arbitrary periodically changing quantity a in the form:

$$a(t)=\sqrt{2}\,Af(\omega t+\varphi_0), \tag{5}$$

where A is the quadratic mean (effective) value; $\sqrt{2}\,Af(\varphi_0)$ is the initial value of the quantity t = 0; and φ_0 is the initial phase.

Since, according to definition

$$\sqrt{\frac{1}{T}\int_0^T a^2(t)\,dt}=A,$$

we find, by taking the quadratic mean value of the right- and left-hand sides of (5), a remarkable property of the function, that the quadratic mean (effective) value of any form function is equal to $1/\sqrt{2}$ irrespective of the period and phase

$$\sqrt{\frac{1}{T}\int_0^T [f(\omega t+\varphi_0)]^2\,dt}=\frac{1}{\sqrt{2}}. \tag{6}$$

The concept of "initial phase difference" or "phase shift" is applicable to periodic quantities of any shape, providing they have the same period. Let the current and voltage be periodic variables characterized by curves of a different shape

$$u(t)=\sqrt{2}\,Uf_1(\omega t+\varphi_1); \tag{7}$$

$$i(t)=\sqrt{2}\,If_2(\omega t+\varphi_2). \tag{8}$$

By an appropriate shifting of the curves along their time axis their analytical expressions can be reduced to the form

$$u(t)=\sqrt{2}\,Uf_1(\omega t); \tag{9}$$

$$i(t)=\sqrt{2}\,If_2(\omega t-\varphi), \tag{10}$$

where $\varphi=(\varphi_1-\varphi_2)$.

In determining from (9) and (10) the wattless power and power factor in any electrical circuit with the current and voltage of any waveform let us introduce the concept of an active current component

$$i_a=\sqrt{2}\,\frac{P}{U}f_1(\omega t)=\frac{P}{U^2}\cdot u(t), \tag{11}$$

which coincides in phase and waveform with the voltage. The mean value of the product of the voltage and the active current component taken over a period

$$\frac{1}{T}\int_0^T ui_a\,dt=2P\cdot\frac{1}{T}\int_0^T[f_1(\omega t)]^2\,dt=P \tag{12}$$

is equal, according to (6), to the active power P.

The effective value of the active current component

$$\sqrt{\frac{1}{T}\int_0^T i_a^2\,dt}=\frac{P}{U}=I_a \tag{13}$$

we shall call the active current I_a.

The difference between the instantaneous values of the total current and its active component

$$i-i_a=i_r \tag{14}$$

we shall call the reactive current component, and its effective value

$$\sqrt{\frac{1}{T}\int_0^T(i-i_a)^2\,dt}=I_r \tag{15}$$

we shall call the reactive current I_r.

By multiplying (14) by the voltage and taking its mean value over a period, we shall obtain according to (12) and (2)

$$\frac{1}{T}\int_0^T ui_r\,dt=0, \tag{16}$$

which gives in conjunction with (11)

$$\frac{1}{T}\int_0^T i_a i_r \, dt = 0. \tag{17}$$

This proves the orthogonality of the active and reactive current components which are represented by periodic curves of any shape.

By squaring (14), obtaining a quadratic mean value over a period and using (17) we have

$$I^2 = I_a^2 + I_r^2, \tag{18}$$

which would be expected in resolving the current into its orthogonal components.

The above definitions of the active and reactive current components can also be applied to the active and reactive voltage components.

By using (3) and (13) and multiplying (18) by U^2, we obtain

$$S^2 = P^2 + (UI_r)^2.$$

By taking the definition of wattless power given by Fryse (4), we should assume that

$$Q = UI_r. \tag{19}$$

For the power factor we have

$$k_a = \frac{P}{S} = \frac{I_a}{I} = \frac{\sqrt{I^2 - I_r^2}}{I}. \tag{20}$$

The wattless power and power factor are measured by a device operating on the basis of (12) – see Figs. 1 and 2. In order to obtain the active current component, a differential (two-element) wattmeter W_d is used in a compensation

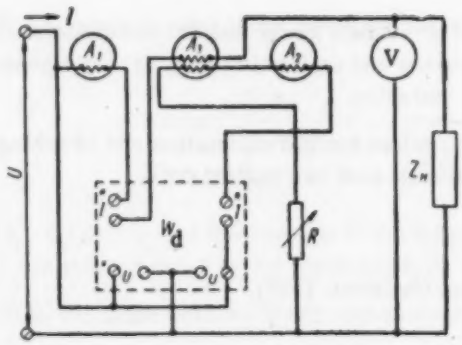


Fig. 1.

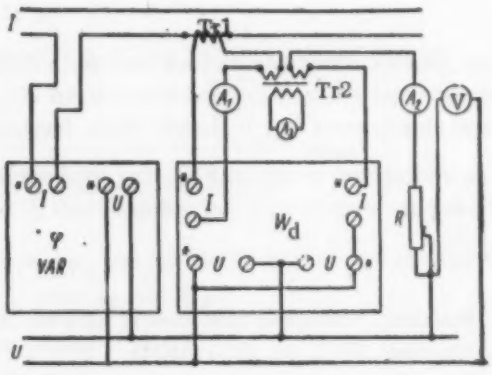


Fig. 2.

(zero balancing) circuit. The parallel circuits of both wattmeter elements are connected to the mains voltage. The series circuit of one of the elements takes the total current and that of the other element the current which coincides in shape and phase with the mains voltage.

By means of a manual or automatic adjustment of the nonreactive resistor R the wattmeter pointer is set to zero. This setting corresponds to equal torques

$$\frac{1}{T}\int_0^T u \cdot i \cdot dt = \frac{1}{T}\int_0^T u \cdot \frac{u}{R} \cdot dt. \tag{21}$$

From (14) and (16), we have

$$\frac{u}{R} = i_a. \tag{22}$$

Thus, the active current component will flow through the series circuit of the differential wattmeter's second element, providing the torques are balanced. By means of the total current and its active component, it is not difficult to obtain the reactive component by using a differential transformer Tr2 (Fig. 2).

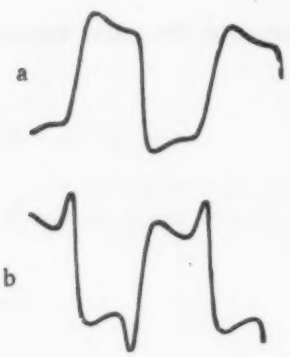


Fig. 3.

The effective value of the current reactive component can be measured either with an ammeter connected to the secondary winding of the differential transformer (Fig. 2) or with a moving iron ammeter which has two identical windings connected in opposition (Fig. 1).

Having measured by means of ammeters A_1, A_2, A_3, and voltmeter V the effective components of the currents and the voltage, we can determine from (19) the wattless power and from (20) the power factor.

The above method of measurement was tested by the author in an electrical circuit with a mixed load. The voltage and current oscillograms are shown in Fig. 3 (curves a and b respectively). The convergence of results, i.e. the agreement between the measurements and formulas (13), (18), and (4) was good within the tolerances of the measuring instruments used.

The above measuring method has all the advantages of the compensation (zero balance) method, provides a high degree of accuracy, does not require a 90-degree phase shift in the instrument's measuring circuit, does not depend on the waveform of the current or the voltage, is applicable to a wide frequency range and to circuits with nonlinear elements (including rectifiers).

Both the current and voltage may contain direct components. It is also possible to measure pulsed currents and voltages providing oscillations are not produced in the moving part of the differential wattmeter.

CONCLUSIONS

The above method can be used both for a direct measurement of wattless power and the power factor in single phase commercial and audio-frequency circuits (Fig. 1) and for checking and calibrating (Fig. 2) single phase VAR meters and phasemeters (φ), including those designed for sinusoidal variables.

The differential wattmeter is being used successfully in compensation method calibration and checking of three-phase phasemeters with two voltage coils [5 and 6] and phasemeters with two current coils.

LITERATURE CITED

1. C. Budeanu, Puissances reactives et fictives Inst. Nat. Roumain. (Bucarest, 1927).
2. A. Fraenkel, ETZ, 49, H. 3 (1928).
3. S. Fryse, Przeglad Elektrotechniczny, Z. 7 (1931).
4. S. Fryse, ETZ, 53, H. 25, 26, 29 (1932).
5. P. B. Usatin, Author's Certificate No. 103671 of December 15, 1954.
6. Instruction 194-57 for testing phasemeters.

BASIC PROPERTIES OF ELECTROMECHANICAL PHASE METERS

E. S. Polishchuk and A. D. Nesterenko

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 41-44, June, 1961

Electromechanical phase meters, including those of the electrodynamic type, are most widely used. We give below the basic design formulas for torque, scales, and principle errors of these phase meters. These conclusions can be applied easily to phase meters of other systems.

The shape of the scale and specific restoring torque of electrodynamic phase meters. A balance of the moving part of the instrument, whose schematic is shown in Fig. 1, is obtained when the sum of the torques acting on moving coils S_1 and S_2 is equal to zero. On this basis it is not difficult to find the scale equation which is equal to the relation between the rotation angle α of the instrument's moving part and the phase angle φ:

$$\alpha = \tan^{-1}\left[\frac{k_1 I_1}{k_2 I_2} \cdot \frac{\cos(\varphi - \psi)}{\cos(\gamma - \varphi + \psi)\sin\beta} + \cot\beta\right], \tag{1}$$

where I_1 and I_2 are the currents in coils S_1 and S_2; γ is the phase angle between currents I_1 and I_2; ψ is the phase angle between current I_1 and voltage U; β is the space angle between the fluxes in coils S_1 and S_2; k_1 and k_2 are constant coefficients.

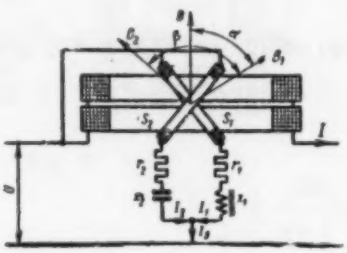


Fig. 1.

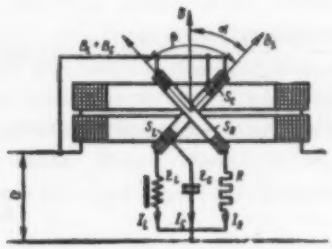


Fig. 2.

For a three-winding phase meter, whose schematic is shown in Fig. 2, we find in a similar manner:

$$\alpha = \tan^{-1}\left\{\frac{k_R I_R}{k_L I_L} \cdot \frac{\cos\varphi}{\left[\cos(\psi_L - \varphi) - \frac{k_C I_C}{k_L I_L}\cos(\psi_C - \varphi)\right]\sin\beta} + \cot\beta\right\}, \tag{2}$$

where I_R, I_L, and I_C are the currents in coils S_R, S_L, and S_C; ψ_L and ψ_C are the phase angles between currents I_L and I_C and voltage U; β is the space angle between the fluxes in coils S_R and S_{LC}.

If in the three-winding electrodynamic phase meters the conditions

$$k_L = k_C, \quad Z_L = Z_C \text{ и } \psi_L = \psi_C = \psi_{LC} \approx \pi/2 \tag{3}$$

are met, the error due to mutual inductance is eliminated and one due to frequency changes within certain limits is made insignificant.

The scale equation of such phase meters for $\beta = \pi/2$ has the form:

$$\alpha = \cot^{-1}(K\cot\varphi), \tag{4}$$

where

$K=\frac{k_R I_R}{2k_L I_L \sin \psi_{LC}}$ — is the instrument constant which depends on its parameters.

In order to determine the errors of the phase meters due to additional torques, it is necessary to know the specific restoring torque of the instrument for any deflection of the instrument's moving part. The torque is equal to:

for a two-winding phase meter:

$$D_{sp.rst} = k_2 I_2 I \frac{\cos(\gamma-\varphi+\psi)\sin\beta}{\sin\alpha} \text{ g-wt.cm} \quad (5)$$

for a three-winding phase meter:

$$D_{sp.rst} = 2k_L I_L I \frac{\sin\varphi}{\sin\alpha} \sin\beta \sin\psi_{LC}. \quad (6)$$

Errors in single phase electrodynamic phase meters. Errors due to variations in the parameters of the instrument can be determined as the sum of partial derivatives, with respect to the rotation angle of the instrument's moving part, [scale equations (1) or (4)] of $k = k_1 I_1 / k_2 I_2$, γ and ψ (for a two-winding phase meter), or of K, ψ_L and ψ_C (for a three-winding phase meter).

The formula for determining the above errors in a two-winding phase meter will have the form [1].

$$\Delta\alpha = -\frac{\sin\alpha \sin(\beta-\alpha)}{\sin\beta}\left[\frac{\Delta k}{k} - (\Delta\gamma - 2\Delta\psi)\cot\gamma\right] - \frac{1}{\sin\beta\sin\gamma}\left[(\Delta\gamma+\Delta\psi)\sin^2(\beta-\alpha)+k^2\Delta\psi\sin^2\alpha\right] \text{[g-wt.cm]}. \quad (7)$$

Errors in a three-winding phase meter may be determined as [2]

$$\Delta\alpha = -0{,}5\sin 2\alpha\left[\frac{\Delta I_R}{I_R} - 0{,}5\left(\frac{\Delta I_L}{I_L} + \frac{\Delta I_C}{I_C}\right)\right] - \frac{1}{2K}\cos^2\alpha\,(\Delta\psi_L - \Delta\psi_C)\,\text{[deg.]} \quad (8)$$

The effect of additional torques due to any of the above-mentioned causes leads to a deflection of the instrument's moving part from its balanced position by an angle $\Delta\alpha$, whose value can be determined as

$$\Delta\alpha = \frac{D_{ad}}{D_{sp.rst}}, \quad (9)$$

where D_{ad} is the additional torque, $D_{sp.rst}$ is the specific restoring torque.

The authors of this article made a detailed investigation both of two-winding and three-winding electrodynamic phase meters. Below we give the results of these investigations and a comparative evaluation of two-winding and three-winding phase meters.

Errors due to mutual inductance. Errors due to mutual inductance in two-winding phase meters types ÉTF made by the "Tochelektropribor" plant for a nominal frequency of 2500 cps amount to 3-3.5°. In a three-winding phase meter with the same nominal frequency and the same mutual inductance between the fixed and moving coils this error does not exceed 0.2°.

Errors due to nonsinusoidal current and voltage waveforms. The relation of these errors to the measured phase angle obtained both theoretically and experimentally provides sufficient grounds for assertion that the readings of three-winding phase meters are affected considerably less by the current and voltage waveforms than those of two-winding phase meters. Moreover, the sign of the error in three-winding phase meters over the greater part of the

scale depends on the order of the higher harmonic, namely when the current and voltage wave forms contain second and third harmonics this error is of one sign (for a given measured phase angle), and when they contain higher harmonics it is of a different sign. Hence, errors due to different harmonics in the current and voltage wave forms can be compensated.

If a sinusoidal voltage and a nonsinusoidal current are applied to two-winding and three-winding phase meters in either case the cosin of the phase angle between the current and voltage of the first harmonic will be measured.

Errors due to frequency variations. The error in a two-winding phase meter may attain 5-10° for frequency deviations of ± 10% from the nominal value. For instance, phase meter ÉLF has an error of 6.3° at 50 cps [1].

When the frequency deviates from the nominal in three-winding phase meters an error is produced which is due not only to the variation of currents in coils S_R and S_{LC} and of the phase angle between them, but also to additional torques produced by mutual inductance [since with a changed frequency conditions (3) are not fulfilled]. The value of the first component of the error does not depend on the instrument's nominal frequency and amounts to 0.4° for a frequency deviation of ± 10% from the nominal. The second component of the error is directly proportional to the frequency and the mutual inductance between the moving and fixed coils. The effect of the mutual inductance is only apparent at frequencies above 500-1000 cps, for frequencies of 400-500 cps this component can be neglected.

Tests of three-winding phase meters ÉLF-1 and ÉLF-2 with nominal frequencies of 500 and 1000 cps have shown that the total error due to a frequency deviation of ± 10% from the nominal at f_n = 500 cps did not exceed 0.5°, and at f_n = 1000 cps did not exceed 0.8°.

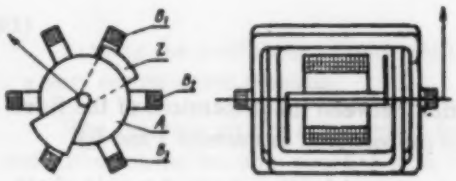


Fig. 3.

Thus, a three-winding measuring mechanism is more suitable for higher-frequency phase meters, as well as for phase meters intended for working in circuits with considerable frequency fluctuations. Multiplying resistors cannot be used with three-winding phase meters intended for working in circuits with frequency fluctuations, since when the frequency deviates from the nominal a multiplying resistance produces a phase difference between the voltage applied to the phase meter's parallel circuit and its component applied to the phase-shifting circuit, thus causing large errors. Hence, three-winding phase meters intended for several nominal voltages should use instrument transformers.

Errors of three-phase electrodynamic phase meters. Special types of errors in three-phase phase meters arise due to the three-phase circuit asymmetry. Investigations have shown that the maximum error due to asymmetry in three-phase phase meters may attain:

a) in single-element three-phase phase meters, and in phase meters which use phase differences between voltages or currents in a three-phase circuit for producing torque, values equal to

$$\Delta k_\varphi \approx \pm (A_U + A'_U + A_I + A'_I); \tag{10}$$

b) in two-element phase meters in a three-conductor circuit values of

$$\Delta k_\varphi = 0, \tag{11}$$

and in a four-conductor circuit

$$\Delta k_\varphi = A'_U A_I , \tag{12}$$

where Δk_φ is the error in measuring the power factor; A_U, A'_U, A_I, and A'_I are the degrees of voltage and current circuit asymmetry respectively.

Basic properties of three-phase moving-iron phase meters. The relation between the rotation angle of the phase meter's moving part, schematically shown in Fig. 3, and the measured phase difference angle has the form:

$$\alpha = at^{-1}\left[\frac{B_1 \cos\varphi_1 + B_2 \cos\beta' \cos(\varphi_1 - \gamma') + B_3 \cos\beta'' \cos(\varphi_1 - \gamma'')}{B_2 \sin\beta' \cos(\varphi_1 - \gamma') + B_3 \sin\beta'' \cos(\varphi_1 - \gamma'')}\right], \tag{13}$$

where B_1, B_2, and B_3 are the values of magnetic induction in the corresponding cross-over coils; β' and β'' are the angles between the directions of fluxes: $\beta' = [\bar{B}_1 \bar{B}_2]$, $\beta'' = [\bar{B}_1 \bar{B}_3]$; γ' and γ'' are the phase angles between the current in coil B_1 and the coils B_2 and B_3, respectively.

In a rotating field $B_1 = B_2 = B_3$, $\gamma' = \gamma''$, $\beta' = \beta''$, and expression (13) assumes the form:

$$\alpha = \varphi.$$

The value of the restoring torque can be found as the mean value of the torque due to the interaction between the rotating field flux with induction $B_{(t)}$ and the pulsating field flux with induction $B_{(0)}$

$$D_{rst} = \frac{1}{T}\int_0^T kB_{(t)}B_{(0)}\,dt.$$

and the value of the specific restoring torque as

$$D_{sp.\ rst} = \frac{\partial}{\partial \alpha}(D_{rst}).$$

For a rotating field it will be:

$$D_{sp.\ rst} = k_0 I I_1 \left[\frac{\text{g-wt.cm}}{\text{rad}}\right]. \tag{14}$$

Here k_0 is a constant coefficient which depends on the size and relation between the dimensions of the fixed coils and the Z-shaped core (it is assumed that the magnetic inductions are proportional to currents I and I_1).

The errors of these phase meters can be obtained from the formulas developed for the electrodynamic phase meter errors.

LITERATURE CITED

1. A. D. Nesterenko, Errors in Single-Phase Phase Meters [in Russian], (Collection of works of the Electrotechnical Institute, Acad. Sci. Ukr. SSR, No. 12, 1955).
2. E. S. Polishchuk, Candidate's dissertation: Measurements of the Power Factor in the Low and Higher-Frequency Ranges [in Russian] (Kiev, 1958).

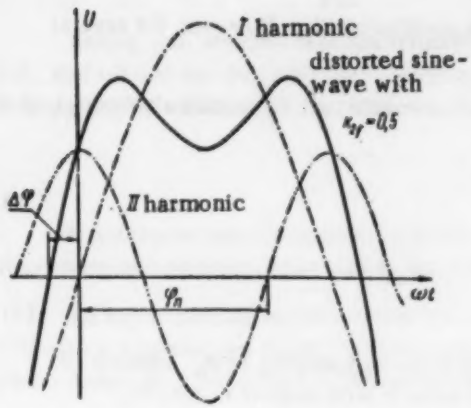
EFFECT OF NONLINEAR DISTORTIONS ON THE ERROR IN MEASURING A PHASE DIFFERENCE BETWEEN TWO VOLTAGES

B. G. Kaduk

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 44-45, June, 1961

The error of electronic phase meters which measure, in determining acoustical resistances, the phase difference between two sinusoidal voltages by means of their transition points through zero [1] is affected by nonlinear distortions of the sinusoidal voltage.

It is shown on the figure attached that the effect of nonlinear distortions on the measurement error consists in the shifting of the zero intersection point in the distorted sine-wave with respect to that point in the first harmonic.



Thus, in measuring the phase angle between fundamentals an error $\Delta\varphi$ is committed, in which $\Delta\varphi$ is the phase difference between the zero intersection point of the distorted sine-wave and that of the first harmonic.

The displacement of the zero intersection point in a general case can be expressed as the root of the equation:

$$\sin\omega t-\sum_{n=2}^{n} K_{nf}\sin(n\omega t+\varphi_n)=0. \tag{1}$$

Coefficients K_{nf} is the nonlinear distortion factor of the n-th order

$$K_{nf}=\frac{U_n}{U_1}. \tag{2}$$

The solution of equation (1) can be written in a general form:

$$\Delta\varphi=\omega t_0=f(K_{2f},\ K_{3f},\ \ldots K_{nf},\ f_2,\ f_3,\ \ldots\ \varphi_n). \tag{3}$$

Finding the possible maximum shift in the zero transition point with respect to 2 (n-1) independent variables is a very complicated problem.

The function attains a maximum for three values of the independent variables for which their first order partial derivatives either become equal to zero or do not exist, and second order derivatives are smaller than zero.

$$\begin{gathered}\frac{\partial\Delta\varphi}{\partial K_{2f}}=0;\quad \frac{\partial\Delta\varphi}{\partial K_{3f}}=0;\ \ldots\quad \frac{\partial\Delta\varphi}{\partial K_{nf}}=0;\\ \frac{\partial\Delta\varphi}{\partial\varphi_2}=0;\quad \frac{\partial\Delta\varphi}{\partial\varphi_3}=0\ \ldots\quad \frac{\partial\Delta\varphi}{\partial\varphi_n}=0.\\ \frac{\partial^2\Delta\varphi}{\partial K_{2f}^2}<0;\quad \frac{\partial^2\Delta\varphi}{\partial K_{3f}^2}<0;\ \ldots\quad \frac{\partial^2\Delta\varphi}{\partial K_{nf}^2}<0;\end{gathered} \tag{4}$$

$$\frac{\partial^2\Delta\varphi}{\partial\varphi_2^2}<0;\quad \frac{\partial^2\Delta\varphi}{\partial\varphi_3^2}<0;\ \ldots\quad \frac{\partial^2\Delta\varphi}{\partial\varphi_n^2}<0. \tag{5}$$

Having assumed the measuremem limits of the independent variables, it is possible to find the maximum value by comparing the maxima of the functions inside the area with their values on the contour.

Let us investigate the relation of $\Delta\varphi$ to nonlinear distortions of the sinusoidal voltage. Although there exist about seven different conceptions for the nonlinear distortion factor, we shall henceforth adhere to coefficient K_f given in several standards and most frequently used in radio measurements

$$K_f=\frac{\sqrt{\sum_{n=2}^{n} U_n^2}}{U_1}; \tag{6}$$

$$K_f=\sqrt{\sum_{n=2}^{n} K_{nf}^2}. \tag{7}$$

It is impossible to investigate in a general form the relation $\Delta\varphi = f(K_f)$ according to the aforementioned method of finding the maximum value of $\Delta\varphi$, since the expression for K_f contains $\sum_{n=2}^{n} K_{nf}^2$, but the initial phase angles φ_n do not figure at all in the expression for the nonlinear distortion coefficient K_f. However, for several simple cases encountered in practice it is possible to find $\Delta\varphi = f(K_f)$.

Let us examine the case when the sine wave with a nonlinear distortion coefficient K_f contains only one higher harmonic. Then:

$$K_f = K_{nf}, \tag{7a}$$

$$\sin \omega t - K_{nf} \sin (n\omega t + \varphi_n) = 0. \tag{1a}$$

The condition for a maximum displacement of the zero intersection point with respect to φ_n consists of $\partial\omega t/\partial\varphi_n = 0$. In order to meet this condition, let us differentiate (1a) and solve it with respect to $\partial\omega t/\partial\varphi_n$

$$\frac{\partial \omega t}{\partial \varphi_n} = \frac{K_{nf} \cos (n\omega t + \varphi_n)}{[\cos \omega t + nK_{nf} \cos (n\omega t + \varphi_n)]}. \tag{4a}$$

It will be seen that $\partial\omega t/\partial\varphi_n = 0$ for

$$n\omega t + \varphi_n = m\frac{\pi}{2} \quad m = 2K+1 \quad K = 0, 1, 2 \ldots \tag{8}$$

By inserting (8) in (1a), we have

$$\sin \omega t - K_{nf} = 0. \tag{1b}$$

$$\Delta\varphi_{max} = \omega t_0 = \sin^{-1} K_{nf} \tag{3a}$$

If n higher harmonics are present in the distorted sine wave, we can only obtain an approximate relationship $\Delta\varphi = f(K_f)$.

Having differentiated (1) with respect to φ_n and equated the partial derivative $\partial\omega t/\partial\varphi_n = 0$, we obtain an expression of the type of (8) for finding the maximum of $\Delta\varphi$ with respect to variables φ_n. Inserting (8) into (1), we have:

$$\sin \omega t - \sum_{n=2}^{n} K_{nf} = 0. \tag{1c}$$

$$\Delta\varphi_{max} = \omega t_0 = \sin^{-1} \sum_{n-2}^{n} K_{nf}. \tag{3b}$$

By using the well-known inequality, we can write:

$$\frac{\sum_{n=2}^{n} K_{nf}}{n-1} < \sqrt{\frac{\sum_{n-2}^{n} K_{nf}^2}{n-1}}. \tag{9}$$

We can write expression (3b) in the following manner:

$$\Delta\varphi_{max} = \omega t_0 < \sin^{-1} \sqrt{n-1}\, K_f. \tag{3c}$$

Taking into account that the majority of nonlinear distortion meter types (INI-11, INI-12, Hewlett Packard 320, and others) are designed for measuring nonlinear distortion coefficients containing up to the fifth harmonic ($n \leq 5$), formula (3c) will take the form:

$$\Delta\varphi_{max} < \sin^{-1} 2K_f \tag{3d}$$

If nonlinear distortions exist in each of the sinusoidal voltages between which the phase angle is measured, the maximum measurement error due to the nonlinear distortion coefficient is equal to the sum of $\Delta\varphi$ of both channels.

An experimental verification of the effect of nonlinear distortions on the error in measuring the phase angle difference between two sinusoidal voltages, made by means of nonlinear distortion meters INI-12 and an electronic phase meter ÉF-1 have confirmed the computation formulas.

LITERATURE CITED

1. N. P. Polyakov, Pribory i tekhnika éksperimenta, No. 2 (1959).

EQUIPMENT FOR TESTING FRAME-TYPE FIELD-STRENGTH MEASURING SETS BY MEANS OF A REFERENCE INDUCTION FIELD

V. S. Buzinov

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 46-48, June, 1961

The All-Union Scientific Research Institute of Physico-technical and Radiotechnical Measurements (VNIIFTRI) has developed a reference equipment UOP-0.012-50 for calibrating and testing commercial field-strength measuring sets which operate in the range of 10 kc to 50 Mc.

The equipment is based on the application of a reference induction field which can be calculated with sufficient precision [1]. The reference field radiator for testing frame-type field-strength meters consists of a symmetrical frame antenna whose perimeter is considerably smaller than the radiated wave-length. In such a case it is possible to consider that the same current flows at all the points of the frame antenna.

If the field-strength meter frame antenna of radius A_2 is placed within the induction zone coaxially with the radiator antenna of radius A_1 at a distance D, and we denote by r" (Fig. 1) the distance from any point on the radiator frame to the point of observation, we shall obtain the value of the vector potential [2]:

$$A_\varphi = \frac{\mu A_1 I}{2\pi} \int_0^\pi \frac{1}{r''} e^{-j\beta r''} \cos\varphi d\varphi, \tag{1}$$

where

$$\beta = \frac{2\pi}{\lambda};$$

$$r'' = D^2 + A_1^2 + A_2^2 - 2A_1A_2\cos\varphi.$$

If we denote $D^2 + A_1^2 + A_2^2 = K^2$, then for the dimensions adopted in equipment UOP-0.012-50 (for the range of 0.01-10 Mc A_1 = 0.05 m, for the range of 10-50 Mc A_1 = 0.025 m), it is possible to write with an error not exceeding 0.15%

$$\frac{1}{r''} = \frac{1}{K} + \frac{A_1A_2}{K^3}\cos\varphi; \tag{2}$$

$$e^{-j\beta r''} = e^{-j\beta K}\left(1 + j\beta\frac{A_1A_2}{K}\cos\varphi\right). \tag{3}$$

Since $A_2 = r\sin\Theta$ (see Fig. 1), we shall obtain the expression given below by inserting (2) and (3) into (1) and integrating:

$$A_\varphi = \frac{\mu A_1^2 I_r}{4K^3}(1 + j\beta K)\sin\Theta\, e^{-j\beta K} \tag{4}$$

The value of the magnetic field can be obtained by inserting (4) into the relation:

$$\bar{H} = \frac{1}{\mu}\operatorname{rot}\bar{A}.$$

If the frame aerial of the field-strength meter under test is perpendicular to the z-axis the magnetic flux cutting that frame is represented by the projections in spherical coordinates of the component H_r and H_Θ onto the z-axis

$$(H_r)_z = \frac{A_1^2 I}{2K^3}\sqrt{1+\beta^2K^2}\cos^2\Theta; \tag{5}$$

$$(H_\Theta)_z = \frac{A_1^2 I}{4K^3}\sqrt{1-\beta^2K^2+\beta^4K^4}\sin^2\Theta. \tag{6}$$

For small values of Θ it is possible to consider that in the zone of the field-strength meter frame antenna the magnetic field is determined only by component H_r, which is equal to:

$$H_r = \frac{A_1^2 I}{2K^3}\sqrt{1+\beta^2K^2}. \tag{7}$$

Despite the fact that the frame responds to the magnetic component of the field, it is customary to calibrate the readings of the frame-type field-strength meters in values of the electrical component. Such a method of calibration is fully justified, since the field-strength meters operate in a radiation zone in which the relation between the magnetic and electric components are expressed by the relationship

$$E = 120\,\pi H. \tag{8}$$

By inserting (7) into (8), substituting K by its value and taking into account that the number of turns in the radiator is equal to N, we obtain the basic formula for computing the field strength

$$E = \frac{60\,\pi\,NIA_1^2}{(D^2+A_1^2+A_2^2)^{3/2}}\sqrt{1+\beta^2(D^2+A_1^2+A_2^2)}. \tag{9}$$

For $\Theta \leq 10^\circ$ the field strength can be computed by the formula

$$E = \frac{60\,\pi\,NIA_1^2}{(D^2+A_1^2+A_2^2)^{3/2}}\sqrt{1+\beta^2D^2} \tag{10}$$

and for $D \leq 0.01\,\lambda$

$$E = \frac{60\,\pi\,NIA_1^2}{(D^2+A_1^2+A_2^2)^{3/2}}. \tag{11}$$

Equipment UOP-0.012-50 has a number of systematic and random errors.

The systematic errors include:

a) the error caused by the assumption that $\Theta = 0$. In fact, angle Θ may attain considerable dimensions. In such a case the readings of a field strength meter with a frame of radius A_2 will be proportional to

$$\int_0^\Theta [(H_r)_z+(H_\Theta)_z]\,d\Theta$$

and the error due to the use of (7) will be determined by the relation

$$\delta_1 = \frac{\int_0^\Theta [(H_r)_z+(H_\Theta)_z]\,d\Theta}{H_r\,\Theta} - 1. \tag{12}$$

After integration and certain simplifications, we have:

$$\delta_1 \approx \frac{1}{6}\Theta^2. \tag{13}$$

The value of this error with respect to angle Θ is shown in Fig. 2:

b) the error due to the nonsinusoidal waveshape of the radiator frame current, measured by means of a thermal converter TVB-5, is represented by the formula:

$$\delta_2 = \frac{1}{2}k_n^2, \tag{14}$$

where k_n is the nonlinear distortion coefficient of the current source.

The radiator frame is normally fed from oscillators ZG-10, GSS-6, or GS-23, which have a $K_n \leq 10\%$ and, hence, the error due to the nonsinusoidal waveform of the current will not exceed $\delta_2 \leq 0.5\%$;

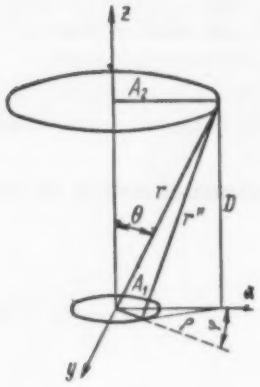


Fig. 1.

c) the error due to stray radiations of the signal generator and insufficient screening of channels. Repeated measurements have shown that this error for the range of 10 kc-10 Mc does not exceed $\delta_3 = \pm 0.5\%$, and for the range of 10-50 Mc $\delta_3 = \pm 1.5\%$;

d) the error due to nonuniform distribution of the current in the frame. It can be considered approximately that current in a symmetrical frame is distributed over half the perimeter of the frame according to the following relationship [3]:

$$I(x) = B\cos\beta(p-x), \tag{15}$$

where B is a constant coefficient; p is the half-perimeter of the frame; x is the distance from the base of the frame to any point on the half-perimeter of the frame.

The error due to a nonuniform distribution of current along the frame perimeter can be expressed by the relation:

$$\delta_4 = \frac{\int_0^p \cos\beta(p-x)\,dx - p}{p}. \tag{16}$$

After integration and certain transformations, we obtain the final expression:

$$\delta_4 = \frac{1}{6}(\beta p)^2. \tag{17}$$

At a frequency of 50 Mc $\delta_4 = 0.4\%$;

e) the error due to the asymmetry of the radiator-frame radiation pattern, which was obtained experimentally with an error for the given equipment equal to $\delta_5 = 1.0\%$;

f) the error due to the ground effect which is determined experimentally. It is known that this error depends on the height of the frames (antennas) above ground, the distance between them, their position with respect to ground, and the parameters of the soil.

Since this method is based on using the induction field, which decreases rapidly with distance, the above error may be reduced to a minimum by selecting suitable distances and heights.

It was found experimentally that with a height above ground of 1.75 m (the most frequently used height for field-strength meters) the error due to the ground effect does not exceed $\delta_6 = 0.5\%$ for a vertical orientation of the antennas and a distance of 1 m between them.

The random errors of the equipment include:

g) the error due to inaccuracies in measuring the values comprising (10). For the values adopted in the equipment this error amounts at its maximum for frequencies up to 10 Mc to $\delta_7 = \pm 1.7\%$ and for 10-50 Mc to $\delta_7 = \pm 2.0\%$. The frequency error of the thermal converter TVB-5, which is used for measuring the current in the radiator frame, is negligibly small over the whole frequency range;

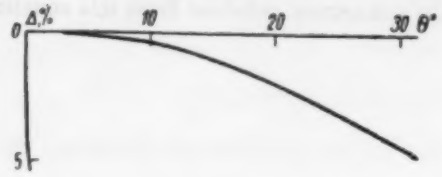


Fig. 2.

h) the error due to deviations from a coaxial position of the reference radiator frame and that of the tested field-strength meter. This error was determined experimentally and for the most unfavorable case amounted to $\delta_8 = \pm 0.3\%$.

The systematic errors of this equipment were investigated and eliminated. Thus, the maximum error of the reference equipment for testing and calibrating field-strength meters is reduced to the sum of random errors and uneliminated parts of systematic errors amounting in the range of 10 kc-10 Mc to $\delta = \pm 2.5\%$ and in the range of 10-50 Mc to $\delta = \pm 4\%$. The above error of the reference equipment fully meets modern requirements, since frame-type field-strength meters have, as a rule, an error not less than ± 15% in the range of 50 Mc.

LITERATURE CITED

1. F. Termen and D. Pettit, Measurement Techniques in Electronics [in Russian translation] (Foreign Literature Press, Moscow, 1955).
2. L. D. Gol'shtein and N. V. Zernov, Electromagnetic Fields and Waves [in Russian] ("Sovetskoe radio" Press, Moscow, 1956).
3. S. Shchelkunov and G. Friis, Antennas [in Russian] ("Sovetskoe radio" Press, Moscow, 1955).

FREQUENCY CHECKING BY MEANS OF HIGH-Q QUARTZ-CRYSTAL RESONATORS

L. D. Bryzzhev

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 48-50, June, 1961

When the relation of the stability of quartz crystal oscillators' frequency with respect to various factors is investigated, the frequency difference between the tested and reference oscillators is normally measured.

In this article the author analyzes resonance testing methods in which the quartz crystal resonators are tuned to the tested frequency, and frequency deviations are determined by the phase-shift or by the signal across the bridge diagonal.

Modern high-Q quartz crystal resonators with their high slope phase characteristic make it possible to check frequency variations by the resonance method with a relative error of 10^{-10} to 10^{-11}.

Let us first examine the phase sensitivity of a circuit (Fig. 1a) consisting of a quartz crystal resonator which is connected in series with an ohmic resistance r.

The frequency at which the quartz crystal resonator is equivalent to resistance R we shall assume to be basic. In this case the input and output voltages are in phase. When the frequency is raised there appears an equivalent inductance L_e (Fig. 1b), and when it is lowered there appears an equivalent capacitance.

Let us denote the equivalent reactance which then arises by χ_e.

By denoting with L and C the inductance and capacitance of a crystal resonator equivalent circuit in series resonance we can find the value of χ_e in terms of these parameters and of frequency:

$$\chi_C = \omega L - \frac{1}{\omega C}. \tag{1}$$

At the series resonant frequency $LC\omega_0^2 = 1$. By inserting the value of the inductance obtained from this equality into (1), we have

$$\chi_C = \frac{\omega}{C}\left(\frac{1}{\omega_0^2} - \frac{1}{\omega^2}\right).$$

For small deviations of ω from ω_0 this expression can be simplified and written in the form:

$$\chi_C = \frac{2R}{\omega RC} \cdot \frac{\Delta\omega}{\omega}. \tag{2}$$

Taking into consideration that $1/\omega RC$ is equal to the resonator Q-factor, we obtain from (2)

$$\chi_C = 2QR\frac{\Delta\omega}{\omega}. \tag{3}$$

The reactance caused by the frequency deviation produces a phase difference φ between the current and the voltage.

Fig. 2 shows the voltage vector diagram. In resistor r the voltage and current are in phase, and according to the diagram

$$\tan\varphi_B = \frac{\chi_C}{r+R}. \tag{4}$$

For small angles φ_B = AC/AB and φ = AC/AO. By cancelling AC, we have $\varphi = \varphi_B$ (AB/AO.

For $\chi_e \ll R$, AB/AO = r/R and $\varphi = \varphi_B$ r/R. By substituting in (4) tan φ_B by φ_B, we have:

$$\varphi = \frac{\chi_C}{r+R} \cdot \frac{r}{R}. \tag{5}$$

By inserting in (5) the value of χ_e from (3), we obtain after transformation the basic relationship:

$$\varphi = \frac{2Q}{1+\frac{R}{r}} \cdot \frac{\Delta\omega}{\omega}. \tag{6}$$

For r = R

$$\varphi = Q\frac{\Delta\omega}{\omega}. \tag{7}$$

For frequency variations of $1 \cdot 10^{-10}$ and at $Q = 10^7$ expression (7) provides φ = 0.001 rad.

Such a quantity can be resolved by a normal oscilloscope with a small additional gain.

Connecting the measuring circuit in parallel with the quartz crystal element will affect to a certain extent the phase relationships. Let us now show that this effect can be neglected.

Let us assume that the measuring circuit in the parallel connection is equivalent to capacitance C_0 and that its reactance is considerably larger than the equivalent impedance of the quartz resonator. By expressing this capaci-

tance in terms of a series capacitance, we have

$$C_s = \frac{1}{\omega^2 C_0 R^2}. \tag{8}$$

In order to compensate this capacitance, it is necessary to fulfill the following condition:

$$\frac{1}{\omega C_s} = \omega L_e = \chi_e.$$

By combining this equation with (8) and (3), we obtain

$$\frac{\Delta\omega}{\omega} = \frac{\omega R}{2Q} C_0. \tag{9}$$

For 100 kc quartz resonators of the KhGIMIP (Khar'kov State Institute of Measures and Measuring Instruments) the $Q = 10^7$ and R = 100 ohm, whence from (9) we have

$$\frac{\Delta\omega}{\omega} = 3 \cdot 10^{-12} C_0,$$

where C_0 is expressed in micromicrofarads.

Thus, the parallel connection of a capacitance of 10 $\mu\mu$f will result in a relative frequency variation of the order of $3 \cdot 10^{-11}$.

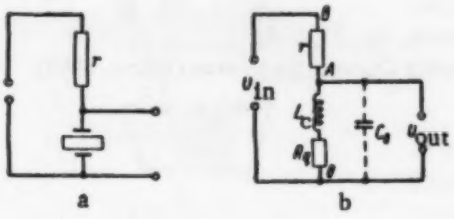


Fig. 1.

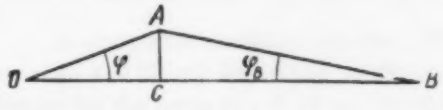


Fig. 2.

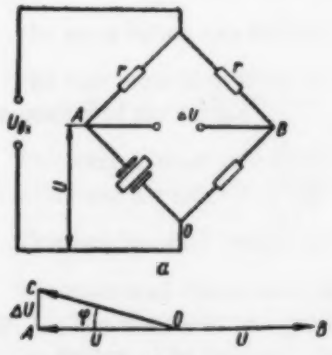


Fig. 3.

The possible variations of this capacitance will have an even smaller effect.

In [1] a recording device with a phase drift of $2 \cdot 10^{-4}$ rad per 8 hr is described. By using such a device it is possible to record frequency variations with an error of $2 \cdot 10^{-11}$.

Let us now examine a second method which uses the bridge circuit shown in Fig. 3a. The corresponding vector diagram is shown in Fig. 3b.

When the bridge is balanced vectors OA and OB are equal and the voltage across the bridge diagonal is equal to zero. When the equivalent quartz impedance becomes reactive owing to a variation in frequency, vector OA will rotate through angle φ into position OC. The modulus of the vector for small angles will remain practically constant. Angle φ will be determined as before by relationship (6). On the other hand, for small angles $\varphi = \Delta U/U$, where ΔU is the voltage across the diagonal and U is the voltage across the quartz resonator.

By inserting this value into (6) we obtain the basic relationship for this method:

$$\frac{\Delta U}{U} = \frac{2Q}{1 + \frac{R}{r}} \cdot \frac{\Delta\omega}{\omega}. \tag{10}$$

For an equal-arm bridge we have

$$\frac{\Delta U}{U} = Q \frac{\Delta\omega}{\omega}. \tag{11}$$

A more general analysis of bridge circuits is given in [2].

For a quartz resonator with a Q-factor of 10^7, a voltage of 0.5 v across it and a frequency variation of $2 \cdot 10^{-11}$ we shall obtain a $\Delta U = 0.0001$ v. Registering such a voltage by means of a narrow-band amplifier does not present any difficulties.

In conclusion, let us make a few remarks on the tuning of quartz resonators by means of series capacitors.

In order to determine the sensitivity of such tuning, let us use the obvious relationship:

$$\frac{\Delta\omega}{\omega} = \frac{C}{2C_1} \cdot \frac{\Delta C_1}{C_1}. \tag{12}$$

In this expression, as before, we assume that C is the capacitance of the quartz resonator equivalent circuit for series resonance, and C_1 is the capacitance of the additional capacitor.

For 100 kc quartz resonators of the KhGIMIP the equivalent capacitance is C = 0.0015 μμf. For a C_1 = 250 μμf we obtain from (12)

$$\frac{\Delta\omega}{\omega} = 3 \cdot 10^{-6} \frac{\Delta C_1}{C_1}.$$

From this example it will be clearly seen what stringent requirements must be specified for the constancy of the tuning capacitor.

In order to ensure a frequency stability of $3 \cdot 10^{-11}$, the random capacitance variations must not exceed 0.001%.

Variable capacitors cannot provide such a constancy. In such a case a box of highly stable fixed capacitors with a parallel small variable capacitor should be used.

LITERATURE CITED

1. M. E. Zhabotinskii and E. I. Sverchkov, Pribory i tekhnika éksperimenta, No. 3 (1956).
2. A. D. Nesterenko, Basic Computations for Balanced Electrical Measuring Circuits [in Russian] (Kiev, 1953).

MEASUREMENTS OF VOLUME

CHECKING AUTOSATURATORS AND AUTOMATIC MACHINES FOR MEASURING OUT AERATED WATER

A. N. Pavlovskii

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 50-53, June, 1961

At present the measuring out and selling of aerated water with or without syrup is done by means of automatic machines or autosaturators in which the syrup is mixed by the stream of the aerated water. Hence, the checking of commercial automatic machines and autosaturators presents a difficulty in separating the streams of water and syrup.

This article deals with problems arising in the checking of automatic machines and autosaturators which the author encountered in their state testing and in personal experience.

At present automatic machines AT-26, AT-48, AT-14, AT-114, ATK-2, ATK-2M, and AT-2MA and autosaturator AS-1 are being used.

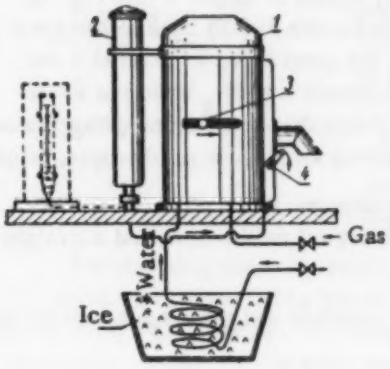


Fig. 1.

In automatic machines AT-26 and AT-48 the rationing is based on measuring the quantity of liquid which passes through an opening or a cross section of a tube for a given time interval. It has been established that a fixed quantity of liquid will pass through an opening per unit of time providing the pressure and viscosity of that liquid remain constant. Hence, in such automatic machines the size of the syrup ration will depend on the measuring time, a constant syrup pressure in the container, the syrup viscosity and its level in the container.

Automatic machines AT-14, AT-114, ATK-2, ATK-2M, and AT-2MA, as well as the autosaturator AS-1 are equipped with syrup measuring devices which operate on the principle of a piston pump. The syrup is sucked into the measuring cavity of this pump and then ejected from it by the pressure of the aerated water at the instant when it is being served.

The size of the syrup ration depends on the aerated water pressure, the hydraulic resistance at the input and output of the syrup rationing device, as well as on the size of the piston stroke in the measuring cavity of the pump.

In automatic machines and the autosaturator the water ration amounts to 180 ml. The syrup ration is fixed between 15 and 20 ml, depending on the cost of the syrup. The maximum permissible deviations from the above rations amount for the syrup to ± 1 ml and for the aerated water to ± 10 ml.

The checking of the automatic machines and autosaturators AS-1 consists in determining the actual values of syrup and water rations and their quality.

The syrup ration can be checked by measuring its volume, or its density and the density of the drink.

The first method enables the volume of the ration to be measured directly but does not provide an assessment of the quality of the drink.

The second, more complicated method, makes it possible to determine by indirect means the value of the syrup ration and the quality of the drink.

This article deals with problems related to the first method.

The system of connections and the relative position of the autosaturator AS-1 and the syrup containers is shown in Fig. 1. The basic unit of the autosaturator 1 consists of the saturator pump with the mixing chamber and the syrup rationing device. The first unit provides the rationing and saturation of water, and the second the rationing and ejection of syrup.

All the processes connected with the preparation of aerated water with or without syrup are automatic and amount to the turning of one or two handles.

The syrup is fed from container 2 to the autosaturator's syrup-rationing device when handle 4 is turned, and then is ejected from it together with the aerated water when handle 3 is subsequently turned.

For serving aerated water without syrup handle 3 alone is turned. Handles 3 and 4 are returned to their normal position automatically.

The syrup rationing device of the autosaturator AS-1 is shown in Fig. 2. Its basic unit consists of a rationing pump comprising a cylinder 1 and a packed piston 6 with its rod 5. Piston rod 5 is sealed by means of a rubber sleeve 9 in the place where it passes through the cylinder bottom 7, and its end is fixed to plate 12 which is connected by two springs 2 to plate 3 fixed to the top of the pump. The springs tend to hold the piston in its upper position.

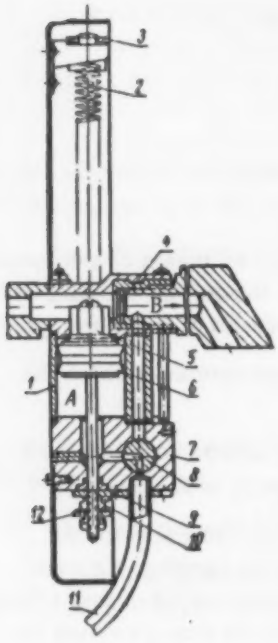


Fig. 2.

The pump's measuring cavity A is adjusted by changing the piston stroke by screwing up nut 10 at the lower end of rod 5.

When a ration is being served, the water pressure which is established in front of the pulverizing filter 4 forces the piston down extending spring 2. If tap 8 of the syrup rationing device is not set to the serving position by means of handle 4 (see Fig. 1), the syrup contained in cavity A is forced along tube 11 (see Fig. 2) back to the syrup container. If the tap is set to the serving position, the syrup is fed to channel B and supplied together with the aerated water into the customer's glass. When the water ration has been poured out, the pressure above the piston drops and under spring pressure the piston returns to its upper position, sucking in at the same time another syrup ration.

In checking the rations delivered by the autosaturator AS-1, 250 ml calibrated cylindrical glass measures and 200 ml burettes with 0.2 ml calibrations and a straight tap are used as measuring devices.

The aerated water with or without syrup is checked by means of calibrated cylinders and the syrup by means of burettes.

For checking purposes ones of the autosaturator syrup containers is removed and replaced by a burette. The lead-out pipe of the second syrup container is closed by means of a stopper. The burette is filled with syrup. After a certain time which allows for the syrup to flow down the walls of the burette and for the passage of air bubbles, the burette tap is opened and the autosaturator connection is washed out by passing through it 3-4 rations of aerated water with syrup. Then 5-6 test rations of the drink are poured out with each syrup dose measured on the burette scale. These measurements are made 15-20 sec after the serving of each drink ration has been completed.

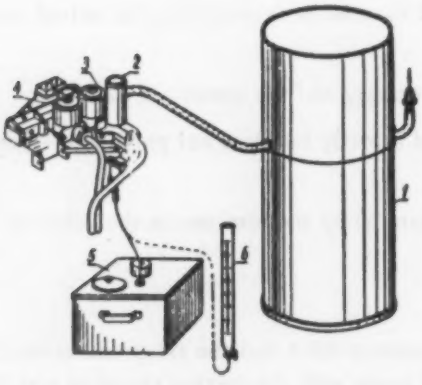


Fig. 3.

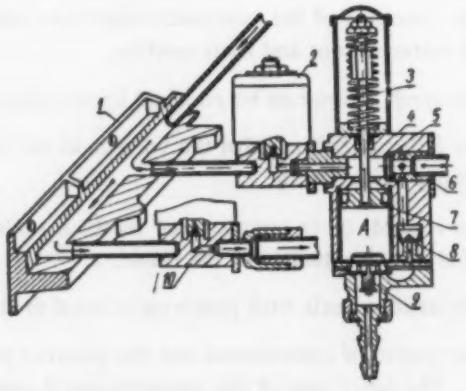


Fig. 4.

In automatic machines AT-14, ATK-2, and ATK-2M the autosaturator AS-1 is mounted separately from the syrup rationing device. The autosaturator handle is operated by an electric motor through a reduction gear by means of a cam mechanism. The motor connects a microswitch whose contacts are closed by the coin which passes into the coin box. The syrup is fed to the rationing device from a container which is placed below it. The water is cooled by a refrigerating unit.

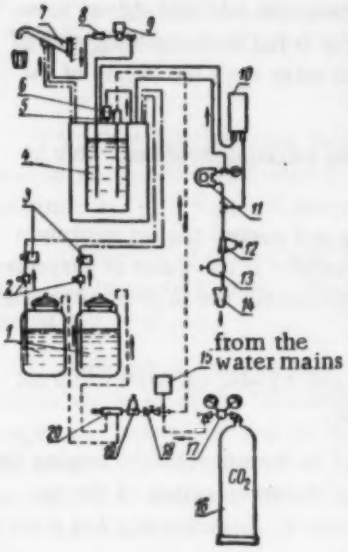


Fig. 5.

The automatic machine AT-114 contains a water-cooling saturator 1 type VUS-2, which is enclosed in a lagged jacket with a cover. The method of connecting the autosaturator, syrup rationing device 2, and the syrup container 5 is shown in Fig. 3. The saturator operation is controlled by two end microswitches which operate, through a system of relays, three solenoid-driven valves. One valve (not shown in Fig. 3) serves to feed the water into the saturator, valve 3 delivers the aerated water with, and valve 4 without, the syrup.

Fig. 4 shows the syrup rationing device with the solenoid-driven valves. When valve 2 solenoid is operated its core is lifted and opens the flow of water from container 1 through the syrup rationing device 4. Under the effect of the water pressure in front of the pulverizing filter 5, the syrup rationing device piston 7 is pressed down and forces out the syrup from cavity A through the return valve 8 and channel 6 into the water stream. When the water ration has flown through, valve 2 is closed by means of a repeated pulse, the pressure over piston 7 drops, and under the pressure of spring 3 the piston returns to its initial position, sucking in at the same time through valve 9 a new ration of syrup from the syrup container. Aerated water without syrup is poured out through valve 10 by the action of an appropriate pulse.

In checking automatic machines AT-14, AT-114, ATK-2, ATK-2M, and ATK-2MA for the purpose of determining the values of the syrup and aerated water ration, as well as for checking the AS-1 water saturator, 250 ml and larger calibrated cylindrical glass measures and 200 ml calibrated burettes are used.

For checking the syrup ration, burette 6 (see Fig. 3) is suspended at the height of the syrup container, filled with syrup and connected by means of a thick-walled tube to the syrup rationing device nipple, from which the tube of the syrup container has been removed. After a settling time interval the syrup ration supplied by the automatic machine is checked in the same manner as is done in the case of autosaturator AS-1.

Above we have indicated the phenomena affecting the syrup ration in automatic machines which operate on the principle of volume measurements. Hence, in inspections and checking, special attention should be paid to the tube connecting the syrup container to the rationing device. A thin tube suffers deformations during the suction of the syrup from the container, thus causing additional resistance which prevents the rationing device cavity being completely filled. The same effect is produced by a tube which is either twisted, punctured, has a small diameter, or contains an additional resistance, for instance, in the form of an inserted ring or a metal pipe section with a small opening.

In such cases the checking will not be correct since it will not reproduce the normal operating conditions.

The method of connecting automatic machines AT-26 and AT-48 is shown in Fig. 5. Equal rations of syrup and water will pass in equal time intervals through the automatic machine valves, providing the pressure and viscosity of the liquid remain constant. The uniformity of rationing depends on the operation of the time relays, the reduction gear, and the water and gas pressure relays which provide the constant pressure in the water and gas pipe lines.

In its operation the automatic machine passes the mains water through a rough filter 14, a fine filter 13, and a reduction gear 12 to pump 11, which forces it under increased pressure into the refrigerating coil of saturator 4, and then through jet 5 and atomizer into the saturator tank where it is saturated with gas. The water in the saturator is maintained at a constant level by means of the automatic level transducer which controls pump 11 according to the position of the level. The aerated water is driven under gas pressure through a tube to the solenoid-driven valve 9. As soon as a pulse from the dropped coin is received and the button marked "without syrup" is depressed, the solenoid-driven valve 9 is operated, and the water flows through the flow-regulator 8 and tube 7 into the customer's glass. The water will flow until the time relay which cuts off the current from the solenoid coil is operated.

Carbon dioxide is fed to the automatic machine from cylinder 16 through reduction valve 17. On leaving the reduction gear the gas pipe line branches off, one branch is fed through a return valve 6 to the saturator tank 4, establishing there a gas cushion with a constant pressure. This cushion saturates with gas the water fed to the tank and forces it to the solenoid-driven valve. Through the other branch the gas is fed to the stop valve 18 and pressure regulator 19 and then to container 20, from which it enters the syrup tanks 1, establishing in them gas cushions with a constant pressure, thus driving the syrup from the tanks through the syrup availability indicators 2 to the solenoid-driven valve 3.

When the coin measuring device operates and a syrup selecting button is depressed the solenoid-driven valve 3 operates together with the water control valve 9. On passing through valve 3 the syrup is fed to the cooling coil of saturator 4, and from there to tube 7 where it is mixed with aerated water. The time relay stops the supply of the aerated water to tube 7 both when the drink is provided with or without syrup.

The syrup rations are adjusted by varying the output channel cross section of the solenoid-operated valve by means of a setting screw.

The relays for water pressure 10 and gas pressure 15 are fitted in the pipe lines and control the set minimum and maximum pressures for water and gas. These relays disconnect the automatic machine if the water or gas pressure falls below the set limits, and reconnect it as soon as it returns to values within the tolerances which provide normal operation of the automatic machine.

In testing the syrup and water rations provided by automatic machines AT-26 and AT-48, calibrated 100 ml cylindrical measures are used for checking syrup and 250-1000 ml for checking water.

When syrup rations are being checked the solenoid-operated water valve should be disconnected by turning the tumbler lever inscribed "water" to the "off" position. If this is done, the operation of the microswitch of the appropriate coin mechanism will provide a flow of syrup alone without water through tube 7. By collecting 4-5 syrup rations in a calibrated cylinder it is possible to determine their mean value.

It should be noted once more that the value of the ration is affected not only by the pressure and the precision of the time relay operation, but also by the viscosity of the measured syrup.

The fact that the rationing of syrup and water depend on many factors has made it necessary to fit the automatic rationing machine with a very complicated electrical circuit.

At present the production of automatic machines AT-14 and AT-48, as well as of the autosaturator AS-1, has been discontinued. In the near future the production of automatic machine AT-26 will also be discontinued. Automatic machine AT-114 seems to be the best, and on its basis other machines will be produced. Since the automatic machines are designed for an operation during 5-6 years, all the above-mentioned automatic machines and autosaturators will remain in operation for a certain time after their manufacture has been discontinued.

MATERIAL RECEIVED BY THE EDITORIAL BOARD

NEW PRINCIPLES FOR DETERMINING COMPULSORY STATE TESTING OF MEASURING INSTRUMENTS

(Comments on V. D. Alesin's article).

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 53-56, June, 1961

V. D. Alesin's article, published in the 1960, No. 10 issue of this journal has provoked many comments by readers and persons interested in providing uniform, precise, and correct application of measures and measuring instruments in our national economy.

Comrades who have sent their comments on the above article made suggestions for changing the system of planning inspection work. These suggestions have been summarized by the Editorial Board and sent to the Committee for its consideration.

Although in their opinion the testing of instruments should be done according to the manner of their use, M. I. Malakhov, head of the "Komsomolets" plant inspection laboratory, I. M. Veisas, head of the "Tambovkhimash" plant inspection laboratory, and M. S. Bril', chief engineer of the Committee's plenipotentiary administration attached to the Council of Ministers of the Ukr.SSR think that regulations 12-58 already reflect the above principle, since the separation of measures and measuring instruments into three groups according to supplements 1-3 to these rules has laid the foundation for a differentiated approach in determining the principle of compulsory testing, and to the agencies which carry it out. They state that the lists of instrument types divided according to the sphere of their application may have to be extended, but it is not permissible to remove, as V. D. Alesin suggests, these lists from the regulations and compile separate lists for each plant and organization. This can only lead to a complication of the GKL (State Inspection Laboratory) work and a large-scale duplication of testing, carried out by the service inspection agencies, especially since the latter are fully coping with their tasks and in the overwhelming majority of cases provide the required maintenance of measuring equipment at the plants. The permission granted to the plants which are ready for the task to organize their own testing of the instruments, according to the opinion of these comrades, is a progressive measure which encourages a wide development and technical improvement of service inspection agencies, and therefore there are no reasons for its rejection.

Com. Maklakov, chief engineer of the Gor'kii "Gorénergo" plant central laboratory, also considers that all the propositions dealt with in the article are in agreement with the Committee's regulations 12-58 and, hence, the questions discussed in the article should be considered as a clarification of regulations 12-58.

At the same time, the article raises other problems whose solution will make it possible for the GKLs to link their activity direct with production and render practical assistance to the plants in fulfilling their plan for high-quality production. N. V. Malinin, the head of the Gor'kii group of GKLs, considers the following problems to be of this type.

1. Introducing new measurement techniques and raising the quality of manufactured instruments. He states: "The Committee has the monopoly in allowing the marketing of new instruments and withdrawing obsolete instruments from production. However, the Committee does not deal with the best and most efficient distribution of new instruments between establishments."

Com. Malinin cites an instance when in 1960 one of the Gor'kii region factories produced low-grade instruments owing to indirect test methods which were due to the lack of reference instruments. The factory's request for the required reference instruments, presented to the Gor'kii Sovnarkhoz (Council of National Economy) was only satisfied to the extent of 15%.

However, there have been instances when plants received new measuring equipment which they did not require. Com. Malinin suggests on this basis that the Committee of Standards, Measures, and Measuring Instruments, should be entrusted with planning the production and distribution of new measuring equipment, in the first place among the

instrument-making organizations and plants, since it is obvious that if the instrument-making plants are not supplied with the necessary reference instruments it will be impossible to attain the required high quality of instrument production.

2. Specialization of the instrument-producing plants will lead to an improvement in the quality of the manufactured instruments, will eliminate various technical difficulties, and will produce a considerable saving.

Com. Malinin considers that the low quality production of the plant mentioned above was, to a considerable extent, due to the lack of specialization. The plant produces up to 50 various types of instruments; moreover, many of these are not suitable for its type of production. The Gor'kii Sovnarkhoz planned their production in quantities of 15-20 models. Such a large variety of production caused many unnecessary technical difficulties and excessive technological equipment, required retraining of personnel and reorganization of benches, greatly complicating at the same time the dealings with the plant's numerous suppliers of semi-finished articles. There are, on the other hand, plants in the region which according to their method of production could easily deal with the tasks assigned by the Sovnarkhoz.

3. Reorganizing the structure of the service inspection agencies. N. V. Malinin supports the necessity for such a reorganization by an example of a certain plant in the Gor'kii region which has, in his opinion, a more efficient and progressive organization of its service inspection agencies.

Following a long preparation and certain difficulties, the plant established a measuring equipment department with the chief metrologist at its head. The rights and position of this department were specified by an instruction of the plant and the Sovnarkhoz to be equal to those of the main departments of the plant (that of the chief designer, chief technologist, etc.). The rights, duties, structure, and other problems were reflected in the instruction on the measuring equipment department and approved in the appropriate manner.

The essence and advantages of the new structure consist in the basically new approach to the work of the service inspection agencies. Previously, com. Spiridonov A. S., head of the factory Central Laboratory, was responsible for the uniformity of measurements and was in charge of the only designing laboratory, the electrical measurement laboratory. Whereas the laboratory for linear and angular measurements was completely subordinated to and supervised by the head of the Technical Control Division, the thermotechnical laboratory was subordinated to the chief power engineer, the weighing laboratory to the chief mechanical engineer, and the adjustment laboratory to the chief of the tool room. Such an administrative subordination dispersed the engineering personnel, produced incorrect tendencies in the work, inability to decide complicated metrological problems, and in the long run hindered the introduction of continuous inspection and of the automation of testing operations. When the measuring equipment department was set up, all the measuring laboratories were subordinated to one person, the chief metrologist (naturally, he was also the person responsible for the uniformity of measurements), thus producing several advantages.

It became possible to direct purposefully the development of the metrological service in the plant as a whole, to decide collectively complex technological problems, to use rationally and improve the qualifications of the laboratory workers, to plan the work according to the requirements of production, to measure with deep understanding complex parameters, and to experiment and conduct research. At the same time, the new organization has eliminated duplication in the repair and adjustment of instruments, in ordering new instruments, in their development, etc. In the long run the new organizational structure of the service inspection agencies, whose establishment was assisted by the Gor'kii GKL, was completely justified, has great prospects for the future, and should be adopted in all the plants where it is possible.

V. N. Luzgin, head of a control and measuring instruments department, combines the problems raised in V. D. Alesin's article with the discussion of K. N. Katsman's article "On some problems associated with the organization and activity of factory measuring laboratories" (Measurement Techniques Nos. 4, 9, 10 in 1959, and 2, 3, 6 in 1960, and 1 in 1961), and V. Rabinovich's article on "Measuring instrument hire depots are required" (Industrial and Economic Newspaper of January 20, 1960) and thinks that all these problems are the result of a deepening discrepancy between the rising requirements in measuring equipments due to the technical progress of our industry and the methods of applying this equipment.

According to com. Luzgin, this discrepancy is caused by insufficient attention being paid to the practical measures required for improving the condition of inspection of measures and measuring instruments, their repairs and the introduction of improved measuring equipment.

In turn, he makes several suggestions which include the following:

1) to raise the role, authority and responsibility of the GKLs in measuring equipment problems by:

a) supplementing them with highly-qualified, experienced personnel with an appropriate rise in their pay;

b) improvement of the material and technical base (provision of suitable premises and modern test equipment, measuring and other instruments according to local requirements);

c) planning of the work in studying the condition of measuring equipment, improving service inspection, rendering practical help to improve the measuring equipment and scientific and technical assistance for the introduction of new measuring instruments;

2) the unification (in the majority of plants) of all the test laboratories into one Central Test Laboratory on the basis indicated in the draft regulation of the Committee of Standards, Measures, and Measuring Instruments;

3) improvement in the planning of the production and distribution of new measuring equipment and automation components, by concentrating the study of the requirements and compiling requests for new measuring and automation equipment in strictly defined agencies of the Sovnarkhoz and plants;

4) making preparations at the plants for the establishment of a metrologists' department with rights in the sphere of measuring equipment similar to the rights of the chief mechanical or power engineers in their own spheres.

Many remarks and suggestions deal, in addition to rendering assistance to the plants which have not yet properly organized service inspection, also with the establishment of measuring equipment adjustment and repair depots with suitable personnel and appropriate pay, as well as with other questions.

M. I. Malakhov, head of the "Komsomolets" plant inspection laboratory, V. V. Levitskii, technical inspector of the Gor'kii control and checking station of the Stalinsk GKL, suggests that all the depots existing in the region for repairing instruments should be unified into a single common depot under the guidance of the Committee's local agencies. This, in their opinion, would considerably reduce the cost of repairs without resorting to the help of "touring stars" from other regions and districts, and would raise the quality of repairs. A. I. Goncharov, head of an area test laboratory, considers, however, that the Committee's laboratories should not deal with the adjustment and on-the-spot tuning of various complex measuring instruments, since for this purpose it is necessary to have a production workshop and qualified adjusters, who are not easily available. He recommends the strengthening of existing area laboratories and the organization of new ones for various types of measurements directly in the plants. Area laboratories have proved in practice to be useful, they are rendering considerable assistance to the plants; not only do they repair and adjust complex instruments, but also engage in periodic testing of the measuring equipment at the numerous plants which have no inspection agencies of their own.

The suggestion to establish design groups attached to the Committee's local laboratories was not favorably received, since there are other organizations which deal with the development of new and the improvement of existing measuring instruments.

The editorial board has also received other suggestions whose implementation is expected by the local state inspection personnel. E. A. Kraev, head of the Kirov GKL, in particular, thinks that the rural "temporary branches" for measuring equipment render very little help for establishing state discipline in providing a constantly efficient and correct use of measuring equipment. On the one hand, they encourage hasty work, and on the other relieve the leadership of the collective farms, establishments and organizations which possess measuring instruments of their responsibility for the continuous serviceability of the equipment.

In the opinion of com. Kraev, continuous efficiency and precision of measurements can be ensured not so much by state inspections as by the development of service inspection as well as by the strengthening of the heavy inspection and organizational work of the GKLs. Com. Kraev suggests that the amount of inspection work carried out by the GKLs should be reduced by distributing it between the service inspection laboratories and agencies, and by abolishing state testing of certain unimportant low precision instruments.

Editorial Note: Comments on com. Alesin's article on the principles for determining compulsory state testing of measures and measuring instruments (see Measurement Techniques, No. 10, 1960) were published in Nos. 5 and 6 of this journal. The editorial board of this journal considers it advisable to test out V. D. Alesin's proposals in one or two state inspection laboratories for measuring equipment.

I. M. Veisas, head of the "Tambovkhimmash" plant test laboratory, suggests the simplification of certificates for tested instruments, proposing that the same certificate be stamped after each testing, thus indicating that the instrument has passed the test. This will save the inspector's time on filling new certificates and will eliminate waste of paper.

NEW IDEAS FOR REPAIRING AND TESTING MEASURING INSTRUMENTS IN RURAL LOCALITIES

G. V. Savchenko

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 56-57, June, 1961

The prevalent practice of organizing state inspection of measuring equipment in rural districts by setting up temporary branches in district centers and transporting there for checking and repair the equipment from isolated places of the district does not correspond to the growing requirements of our agriculture. The transportation of instruments to district centers involves certain difficulties for their owners, such as the prolonged withdrawal of instruments from their normal use, which disrupts commercial activity, and the unsatisfactory transport conditions for the repaired instruments which often involve their damage, loss of components and the loss of their metrological properties. The transportation of instruments takes many workers and means of transport away from their normal employment.

The Ternopol' GKL (State Inspection Laboratory) set itself the task of eliminating these defects and difficulties, and organized the repair of widely used commercial instruments on the spot.

On the initiative and with the participation of the GKL, five small weighing-equipment repair shops attached to tractor repair stations were unified into a single regional area laboratory, which was supplied with adequate premises at the Glubochekskaya tractor repair station, and fitted with reference instruments, tools, spare parts, and other equipment required for repairs, which were purchased in bulk from the Ministry of Agriculture of the Ukr. SSR.

A large exchange stock of weights, manometers, and electrical rack-mounted instruments for convenient and efficient servicing was set up.

The area laboratory fitted 8 motor trucks with the required apparatus and tools for carrying out repairs on the spot. Liaison between the travelling teams was provided by motorcyclists.

Each travelling instrument-repair team consists of 5-7 qualified mechanics capable of carrying out any required repairs.

The work of such an instrument-repair team equipped with all the necessary instruments is based on the following principle.

According to a set plan, this team accompanied by a government inspector leaves for the district center, where the inspector remains for the required organizational work, with 2-3 mechanics who repair and adjust instruments belonging to the district center organizations. The truck with the remaining mechanics leaves for the repair of instruments on the spot. As the repair work is completed in any given area, the state inspector together with the foreman mechanic visits the collective and state farms and other organizations where the instruments have been repaired in order to carry out their state checking.

The repairs of rack-mounted electrical instruments, three-phase and single-phase electricity meters, manometers, and other instruments are carried out by a special team consisting of three mechanics who travel in a truck equipped with a three-phase generator, an installation for testing three-phase electricity meters, a reference weighted-piston manometer and a set of reference spring manometers. The instruments submitted for repairs are exchanged as often as is necessary for serviceable instruments from the exchange stock.

The repair of instruments according to the above more efficient manner has reduced the time required for the state inspector's and the repair team's visits to the districts by 25%, and raised the volume of repair work, state testing and heavy inspection. The overhead expenses have also been reduced. The cost of instrument repairs on the spot has been lowered by 15-20%.

The state inspector's visits for testing repaired instruments in all the inhabited localities of the district enables him to carry out certain useful work which would have been impossible if temporary branches were organized. Thus, he is able to check the correct application of instruments on the spot, instruct persons who are directly concerned with their use, carry out talks on service inspection of the measuring equipment with persons responsible for the inspection, render organizational and technical assistance in improving the measuring equipment. The state inspector can also take steps to introduce new means of measurement.

In practice such organization of work has proved to be advantageous to the instrument owners, and has greatly raised the adaptability of repair teams, which can now repair all the weighing equipment on collective and state farms and stocking organizations before the harvest.

The repair of measuring equipment on the spot in the Ternopol' region has met with general approval.

REVIEWS AND REPORTS

TESTING CONVEYOR SCALES*

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 57-58, June, 1961

The general principle of weighing loose products on a conveyor belt by means of weights which continuously measure consecutive sections of the belt is well known.**

Indicating scales are used for measuring the weight of the article passing on the conveyor belt over the scales at any given moment, or for measuring the conveyor capacity; summing scales are used for measuring the quantity of the product which has passed over the scales, and controlling scales for regulating the supply of the product.

Readings of the summing scales are used for commercial accounting, determining wages, for bonus payments, etc.; hence, their accuracy is particularly important. Summing scales are passed and approved by the measuring instrument service twice, namely, at the factory and in the place where they are used. At the factory they are statically tested by means of reference weights placed on the platform of the scales. When the measuring instrument service accepts the scales at the place of their application they are installed in their position and operate with the normal load. Further on-site tests are made yearly. The scales are checked at the following intervals: 1 month after their installation, 2 months after the first test, 3 months after the second test and then periodically every three months. Moreover, the scales should be checked every time any alterations are made to the conveyor or when any doubts as to their accuracy arise. The scales should be checked with an unloaded belt by means of reference weights placed on the scale platform. For each load (capacity) relative errors are determined, on whose basis error graphs are drawn, with the scale's weight-carrying capacity divided into 5-6 sections and plotted along the Y-axis (for instance, for a weight carrying capacity of 100 kg per cycle the points are taken at 0, 20, 40, 60, 80, and 100 kg, for a load-carrying capacity of 300 kg they are taken at 0, 50, 100, 150, 200, 250, and 300 kg), and relative errors for each load plotted along the X-axis. The first error curves are plotted for the first checking immediately before the scale adjustments are completed. In order to be able to determine accurately the dispersion of the scale readings, it is recommended to plot several consecutive curves. After the equipment is put into operation curves are plotted periodically once or twice between each checking, which corresponds to a period of 7-15 days. One curve can be plotted for a conveyor length of 30 to 50 m in 10 to 15 minutes.

Between two error curves it is often necessary to calibrate an unloaded conveyor belt at one point only, which corresponds either to zero or the most used carrying capacity. Calibration requires very little time and can be carried out daily. It determines deviations (calibration errors) which can be compensated by means of a calibrating load.

When error curves are plotted for indicating scales before the conveyor belt has been installed, weights of a given value are placed on the scale's platform and the difference between their value and the pointer readings are noted. One investigation for each point of the ascending and descending curves is sufficient. In checking the summing action the mean of at least 10 cycles for each load is taken.

After the installation of the conveyor belt the equipment is calibrated for zero at a definite mean weight of the belt for one or several of its complete revolutions. The same method is adopted for each load which it is required to check. It is, therefore, necessary to determine for each installation the number of cycles to a complete revolution of the conveyor belt. If the complete revolution of the conveyor belt comprises, for instance, 12 cycles, the checking at one point (let us take 20 kg) will be carried out in the following manner. The conveyor belt is set into motion, gradually loaded with the weight (20 kg) and both the cycle-counter and the summator readings are taken. After 12 cycles the summator reading is again noted. The difference between the two summator readings should amount to 240 kg. If any absolute deviations for this point exist (for 20 kg), the relative error is obtained by dividing the absolute error by 240 kg.

---

*From G. Petit's article "Passage et dosage pondéral continu sur bande transporteuse." From the French journal "Mines", 1960, X, No. 4.

**See the book by P. Ya. Al'yanaki, S. I. Gauzner, and others entitled "Weighing Instruments", Mashgiz, Moscow, 1950, and Instruction 55-54 on checking conveyor scales. —Editor.

If the conveyor belt contains in its length an incomplete number of cycles, the appropriate number of complete conveyor revolutions is taken. For instance, for 12.5 cycles two complete revolutions are recorded, and for 12.3 cycles, three complete revolutions.

When the conveyor scales are checked by the above method, the material transported by the conveyor is estimated with an error of the order of 0.5-1%, which is satisfactory for all practical purposes.

INFORMATION

DANISH VIBRATION-MEASURING APPARATUS

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 58-59, June, 1961

The vibration-measuring apparatus of the firm Bruel and Kjaer, which was shown at the Danish electrical measuring instruments exhibition, is of interest as one of the successful versions of a universal (measuring various vibration parameters over wide ranges) vibration-measuring set intended for general purposes. By means of this set it is possible to make a practically complete set of vibration measurements required by modern industry and research organizations.

The vibration-measuring set includes piezoelectric transducers of four types, preamplifiers of two types, cathode followers of two types, spectral analyzers of three types, microphone amplifiers of two types, a calibrating apparatus, and a level recorder.

In describing the facilities provided by this set it should be noted that it is possible to measure by its means peak, rms or mean values of vibration displacement, speed or acceleration; to record curves of vibration displacement, speed and acceleration; to make automatic (recorded) or pneumatic spectral analyses of the tested vibration; to obtain an absolute calibration of the whole channel of the set immediately before measurements; to obtain both automatically (recorded) and pneumatically frequency characteristics of any unit, and of the channel as a whole immediately before measurements.

The firm uses the principle of unit construction, thus making it possible to obtain all the above measurements by combining in different ways the various units which have matched input and output parameters. In addition, each unit has an application of its own.

The set is designed in the main for piezoelectric acceleration-measuring transducers, since they cover the widest range; their stability with time and temperature is provided by a special treatment of the piezoelectric ceramic. The transducers are used in the acceleration range of 0.02-2000 g and have a sensitivity of the order of 35-70 and 6-12 mv/g, depending on the type of the transducer.

In order to extend the low-frequency range (when measuring accelerations down to 2-5 cps), the transducers are used with preamplifiers and cathode followers which have a high input impedance (of the order of 40-270 meg). The preamplifiers include integrating circuits which provide measurements of speed (minimum limit 0.0008 cm/sec) and displacement (minimum limit 0.003 μ) at frequencies of 3 cps and higher.

Frequency analyzers provide spectral analysis in various frequency ranges, depending on the type of the analyzer, and cover frequencies of 2-35000 cps.

It is possible to obtain in conjunction with the level-recorder an automatically recorded vibration spectrum in the range of 20-25000 cps.

The units of the frequency analyzer and microphone amplifier are also used as linear amplifiers and indicating devices in the range of 2-35000 cps. By using a microphone amplifier in conjunction with a level-recorder it is possible to obtain automatic recording of vibrations.

The calibration apparatus incorporated in the vibration-measuring set provides a speedy and easy calibration of the acceleration-measuring channel.

The firm has adopted two different methods of calibrating the vibration-measuring equipment, namely, an absolute calibration at a single frequency within the working range, and a frequency run in relative units in order to obtain the frequency characteristic over the whole working range. The absolute calibration is made by means of a small resonance vibrator with an electromagnetic exciter incorporated in the preamplifier and producing accelerations of 1 g.

For obtaining the frequency characteristic of the vibration-measuring channel a calibration-exciter is used, which consists of a miniature electrodynamic vibration tester whose acceleration is automatically maintained at one level over the whole frequency range. The calibrating exciter is used in the range of 50-30000 cps. It has already been mentioned that the set provides an automatic recording of the frequency characteristic by means of the level-recorder.

The error of the absolute calibration amounts to ± 5%. The firm considers that the error of the vibration measurements made by means of the apparatus shown at the exhibition lies within the same limits.

MEETINGS AND CONFERENCES ON MEASUREMENT TECHNIQUES

Translated from Izmeritel'naya Tekhnika, No. 6,
p. 59, June, 1961

On February 22 to 25, 1961, a conference on production automation and mechanization in the engineering industry was held in Moscow at the N. É. Bauman Higher Technical School.

At the section on the automation of checking, formed at the conference, papers were read on the automation of testing gear-wheels, on new photoelectric instruments for automatically testing dimensions, on automatic testing of inseparable components, etc.

• • •

On February 24, 1961 the 4th plenary session of the Central Administration of the instrument-making industry scientific and technical society was held.

A paper was read at the plenary session on the role of scientific and technical personnel in the development of Soviet instrument-making in connection with the preparations for the 22nd Congress of the CPSU (Communist Party of the Soviet Union).

• • •

A scientific and technical conference of the industrial, scientific, and technical personnel of Leningrad, held on March 6-7, 1961, summed up the work in various branches of measurement techniques and determined the basic trends for their further development.

The following papers were read and discussed at the conference.

1. Basic scientific and technical trends in electrical instrument-making, measurement technology, and metrology.

2. Successes of pyrometric instrument-making and basic tendencies in new developments.

3. Leningrad's achievements in developing methods and instruments for measuring mechanical quantities (mass, flow, pressure).

4. Leningrad's achievements in radio-measuring instrument-making and means for its further development.

5. The development of analytical instrument-making.

6. The present state and future development of optico-mechanical instrument-making in Leningrad.

7. Instruments and means of automation in agriculture and further methods of their development.

8. Achievements in medical instrument-making and its further development.

• • •

A scientific and technical conference on methods and equipment for testing magnetic materials was held on March 20-24, 1961, in Leningrad.

The conference was convened by the Leningrad and the Ukraine branches of the instrument-making industry's scientific and technical society, the D. I. Mendeleev All-Union Scientific Research Institute of Metrology, the Scientific Council on the physics of magnetic phenomena of the Academy of Sciences, USSR, and the Leningrad House of Scientific and Technical Propaganda.

Some 50 papers were read and discussed at the conference.

INTERNATIONAL METROLOGICAL CONFERENCES

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 59-60, June, 1961

The working groups of the International Weights and Measures Bureau's Consultative Committee on standardizing ionizing radiation measurements met in the second half of January, 1961.

Four groups participated in this work, namely, on radiation dosage, radioactive isotopes, on neutron measurements, and on the radium standard.

The groups worked out draft programs of work for the respective laboratories of ionizing radiations measurement standards of the International Bureau of Weights and Measures, and made arrangements for the required premises, equipment, and personnel.

Draft programs were presented and adopted for 1961-62 on international comparisons of standard ionization chambers and reference radioactive and neutron sources.

The working groups prepared appropriate reports for the Consultative Committee on ionizing radiation standards, whose current 3rd session is due to be held in October 1961.

• • •

The Commission for revising the Metric Convention of the International Weights and Measures Committee of the International Bureau of Weights and Measures met at the end of March, 1961.

The Commission carried out the work entrusted to it by the International Committee of Weights and Measures, which was acting in compliance with the resolution of the 11th General Conference on Weights and Measures.

After detailed discussion the Commission expressed its opinion that at present there is no pressing necessity for revising the Convention, and recommended that the International Committee for Weights and Measures request the governments which participated in the Metric Convention to report within 6 months their point of view regarding the necessity for reviewing the Metric Convention, and in the event of an affirmative reply to suggest the amendments which should be introduced in the Convention.

• • •

The 2nd session of the International Weights and Measures Bureau's Consultative Committee for Determining the Second was held in the first half of April, 1961.

At this session (similarly to the first session, held in 1957), the main problems dealt with the establishment and improvement of molecular and atomic frequency standards. The question of international comparisons of molecular and atomic standards, and the organization of an ephemeris time service were also discussed.

The resolution adopted by the Consultative Committee urged the metrological establishments of the various countries to develop their work on molecular and atomic frequency standards.

SYMPOSIUM ON TEMPERATURE MEASUREMENTS HELD IN USA

E. T. Chernyshev

Translated from Izmeritel'naya Tekhnika, No. 6,
p. 60, June, 1961

A symposium on temperature measurements and temperature control in industry organized by the American Institute of Physics, Instrument Society of America, and the National Bureau of Standards (NBS) was held in Columbus (Ohio), USA, on March 27-31, 1961. The symposium was chaired by NBS scientists C. M. Herzfeld and V. A. Vilhack.

228 papers were read at the symposium, covering a temperature range of 0 to $10^{7°}$ K. In addition to American scientists and engineers, the symposium was attended by invited foreign metrologists from the USSR, Britain, FGR, Holland, Australia, and Canada. The Soviet delegation (Candidates of Technical Sciences F. Z. Alieva, M. P. Orlova, and E. T. Chernyshev) presented and read three papers on low temperature thermometry (the works of Prof. P. G. Strelkov and others) and on determining reference points by means of a gas thermometer (the works of A. N. Gordov, I. I. Kirenkov, and others).

Some 40 papers dealt with metrological questions, whose discussion was initiated by the speech of A. V. Astin, director of the NBS, who among other things mentioned Soviet investigations on the technique of measuring temperatures.

The theoretical foundations for reproducing the modern temperature scale were dealt with in the papers read by R. B. Lindsey on "Temperature concepts for systems in equilibrium" and by N. Ramsay on "Thermodynamics and statistical mechanics for negative absolute temperatures." The same problems were dealt with in the papers read by H. B. Gallen, K. E. Schüller, and McNeish.

A basic paper in the sphere of temperature scales was read by the head of the NBS thermal division C. Herzfeld.

D. S. Stimson's (NBS) paper dealt with the revision of the international temperature scale of 1948.

Measurements by means of gas thermometers were described in detail in the paper read by H. Mozer of the Federal Physico-Technical Institute.

The greatest interest was aroused by a large group of papers on low temperature measurements, dealing with platinum thermometry, the application of new acoustical and magnetic techniques in thermometry, and with germanium thermometers. In this group one should note the papers of H. H. Plumb, R. Hadson, Lindenfeld, A. Harper, and V. Kemp, C. Barber, H. van Deyk, H. Preston-Thomas, R. Coruccini, E. Maclaurin, and others.

A very interesting paper on glass thermometers for medium temperatures was read by E. Hall.

A large group of papers dealt with measurements at high temperatures ranging from the melting point of gold to the most high-temperature conditions of plasma. In this group one should note the papers of Z. Tingwald, V. Hill, Z. Hornbeck, B. Brenden, H. Grimm, T. Stratton, and others.

In addition to sections of a general character, the symposium also had sections dealing with temperatures in biophysics, low-temperature applications in medicine, temperature measurements in astrophysics and geophysics.

Translated from Izmeritel'naya Tekhnika, No. 6,
p. 60, June, 1961

The section on technical inspection of quality in engineering and instrument-making of the F. É. Dzerzhinskii Moscow House of Scientific and Technical Propaganda (MDNTP) organized for technologists and the technical control division personnel in engineering and instrument-making, as well as for leading automation specialists in plants, Sovnarkhozes (Councils of National Economy) and scientific research institutes which deal with problems of quality inspection, a series of lectures on the "Organization and methods of technical inspection."

This series includes papers and lectures on the following subjects: the conditions and prospects for improving the technical level of the measuring equipment manufactured by the "Kalibr" and MIZ plants; checking the basic precision parameters in metal-working lathes; method of determining the technical and economic efficiency of introducing control and automatic devices; statistical method of quality control; draft standard for a statistical control method; conditions and means of improving the technical level of measuring instruments made by the Leningrad tool plant and the "Krasnyi instrumental'shchik" plants, and others.

Some of the papers will be published and distributed to the students. Special information leaflets will deal with the new measuring devices produced by our industry.

This series of lectures will be held once a month during 1961.

Establishments wishing to send any of their workers to the above course should transfer 10 roubles 10 copeks per person to the account of MDNTP No. 158538 in the Bauman District of Moscow. Reference "Z-0961" must be indicated.

REVIEWS

HANDBOOK ON THE TECHNIQUE OF LINEAR MEASUREMENTS

G. S. Simkin and I. I. Chechik

Translated from Izmeritel'naya Tekhnika, No. 6,
pp. 61-62, June, 1961
Edited by Prof. P. Leinveber, translated from the German.
Mashgiz, Moscow, 1959, p. 927.

The reviewed handbook consists of 8 chapters, 40 sections, and 151 sub-sections. At the end of almost every section and many sub-sections extensive foreign bibliography is given (over 400 titles of articles, books, and specifications). The material is illustrated by graphs, schematics, and photographs of various types of measuring instruments.

The handbook deals with a wide range of questions, including general principles; basic units of measurement; information on mathematics; design of gauges; manufacture of measuring equipment; the use, checking, and storing of measuring equipment; simple and complex problems in measurements; organization of measurements; application of mathematical statistics, and statistical methods of control; and problems of economics in measurements. The handbook summarizes the experience of German plants based on the ISA and DIN systems. The measuring equipment described in it is mainly German; descriptions are given of some of the measuring equipment made in other countries. The book deals with methods of testing various measuring devices adopted in Germany.

The striving of the authors to cover as wide a range of questions as possible has resulted in an insufficiently full treatment of important sections dealing with testing methods, description of measuring equipment, etc. Thus, for instance, the question of checking block gauges (p. 342 and following pages), and their grading is not dealt with sufficiently, although these gauges are widely used in engineering plants and are essentially the basic means of checking both instruments and block gauges of a lower grade or order; no mention is made of any system for providing uniform measurements and transferring dimensions from the basic measures to the manufactured articles. To some extent the same remarks apply to other types of measurements, in particular to checking angle gauges, measuring wheels (p. 321), checking large-size micrometers (p. 369), checking levels (p. 401), and others. Neither has attention been paid in the book to measurements of large sizes.

On the other hand, certain questions could just as well have been omitted. Thus, for instance, the book gives details in connection with the design of gauges, the manufacture of measuring instruments and scales, although the basic subject of the handbook only concerns the technique of linear measurements.

Certain inaccuracies and errors made by the handbook's author should also be noted. For instance, on p. 86 we read: "In calculating the most probable error from more than two maximum errors δy, the linear summation law will give it too large a value. It is more probable that, firstly, the errors of the measured quantity have different signs and, secondly, that their values are not always equal to the maximum error. Thus, the errors which affect the result may partially cancel one another out. Hence, the summation must be carried out according to the law of quadratic addition of random errors

$$\delta x = \pm \sqrt{\left(\frac{\partial f}{\partial y_1}\delta y_1\right)^2 + \left(\frac{\partial f}{\partial y_2}\delta y_2\right)^2 + \ldots}$$

which is normally, although incorrectly, called the Gaussian law of error summation."

In the above reasoning there are two inaccuracies. Firstly, if it is required to calculate the maximum probable error, the application of a linear summation law is unsuitable, not because it would give the error a large value, but because its probability is very small. Secondly, neither in the theory of probability, nor in mathematical statistics and hence in the theory of errors, is there such a law as "quadratic addition of random errors."

There is a law of quadratic addition of one of the random quantities distribution characteristics, and hence of random error distribution. Such a characteristic of random error distributions is the quadratic mean quantity σ; for random errors such a distribution characteristic is a quadratic mean error, also called σ.

In relation to the above remarks it should be noted that certain formulas given in the book are incorrect and may introduce confusion (formulas on pp. 87, 88, 89, and others).

Neither is it possible to agree with certain reasonings of the authors, for instance, on the "true mean value" and its probability (p. 126). However, we shall not dwell on this.

The second group of shortcomings and defects is connected with the translation of the handbook.

According to the annotation the book is intended for inspectors, mechanics, engineers, and technicians in engineering plants and scientific research organizations. Hence, for the successful application of the material contained in the book it should be presented according to the terminology and basic principles adopted in specifications (GOSTs, regulations, instructions) used in Soviet practice.

However, in the book often there are even no references to the GOSTs (All-Union State Standards), regulations and instructions, for instance, on pp. 227, 228, 248, 342, and 358. Neither are there any references to the appropriate GOSTs on measuring instruments (gauges, micrometers, indicators), and the appropriate instructions of the Committee of Standards, Measures, and Measuring Instruments. In cases when there are references to the GOSTs they are not accompanied by the required explanations.

The editorial board made a mistake in issuing the handbook in the form of a simple, formal translation. It should have been rearranged to suit the requirements of Soviet industry, reflecting the latest achievements of measurement technology. The handbook should not only contain annotations, but also an editor's foreword for a correct orientation of the Soviet reader.

We have some valuable experience in the publication of foreign technical literature. Thus, for instance, as long ago as 1936 the Standartgiz issued a book written by the German professor G. Berndt on "Measurement of angles in engineering," with a foreword which provided the Soviet reader with the correct orientation for reading the book.

We can also quote a more recent example. In 1959 the literature and economic sciences editorial board of the Foreign Literature Press issued a translation of an English language book entitled "Quality control organization in the US industry." The book provides most interesting material for wide circles of Soviet engineers and technicians on the organization of quality control in the US industry. The editor not only checked the book but also wrote a foreword to it amounting to about 10% of its contents. By several examples the author showed the advantages in certain instances of quality control organization in the USA and compared these with the organization existing in the USSR. Moreover, he showed that it is not always advisable to agree with the opinions of the author of the book on the problems of quality control organization.

The reader may not agree with certain statements in the foreword, but the editor's praiseworthy intentions to help the reader's orientation on problems of foreign technology dealt with in the book cannot be denied.

This, unfortunately, was not done in issuing the "Handbook on the technique of Linear Measurements" and, therefore, we cannot agree with the references as to its value made in the annotations.

In the sphere of linear measurement techniques the Soviet Union has many achievements. Many measuring instruments are being produced in the USSR of a higher quality than abroad. Suffice it to note such measuring equipment as N. V. Kushnikov's angle-gauges; Academician V. P. Linnik's instruments for measuring surface roughness; V. S. Chaman's profilometer; the induction "Kalibr-VÉP" profilograph-profilometer which obtained a gold medal at the International Exhibition in Brussels; D. S. Semenov's angle-gauge; an instrument for production testing of dial gauges (developed by the KhGIMIP [Khar'kov State Institute of Measures and Measuring Instruments]); the autocollimator instrument for testing angle-gauges (developed by the KhGIMIP); I. T. Uverskii's contact interoferometer; lever and gear instruments of M. M. Kempinskii and A. A. Monakhov; the opticomechanical instruments of the GOMZ (State Opticomechanical Plant) and other instruments. One can also note the work done by the VNIIM (All-Union Scientific Research Institute of Metrology) in interference measurements conducted under the guidance of M. F. Romanova, the work done in standardizing measurements of geared and worm transmissions, etc.

However, the handbook completely ignores the work of Soviet engineers and metrologists. Even in such a section as that of measurement units various countries are mentioned, with the exception of the Soviet Union. A few references of the translators and the editor noting some of the GOSTs do not save the situation.

Let us dwell on some of the other characteristic failings of the handbook.

The handbook lacks any relative evaluation of the various methods and equipment for linear and angular measurements described in the book. In section "168. Threads", various standards and thread characteristics used in the FGR, GDR, Britain, and USA are given, but nothing is stated about the threads used in the USSR. This does not agree with the annotation which states that the handbook is intended for wide circles of workers in industry, who hardly require any information on threads which are not used in the USSR. It is obvious that this part of the handbook can only be useful for a very limited circle of specialists.

The necessity of section "169. Meshing", for workers in industry, and students in higher and secondary schools is doubtful. The material contained in this section will not only fail to assist them, but will confuse them. Important work has been conducted in the Soviet Union in standardizing geared and worm transmissions and various gear-measuring instruments, as a result of which many new standards have been developed and approved, such as GOST 1643-56; GOST 9178-59; GOST 1758-56; GOST 3675-56; GOST 6512-58; GOST 5368-58; GOST 9459-60, and others, which are being assimilated and used by our industry. Therefore, workers in industry should be helped to study these specifications instead of other propositions which are only of interest to a narrow circle of specialists.

The section "222. Block Gauges" also fails to provide a correct orientation of the reader, since it does not agree with the new GOST 9038-59 and instruction 100-60 (replacing OST 85000-39) which is the basic specification for the use and testing of block gauges.

The testing procedure described in the handbook should have been examined side by side with that adopted in the USSR.

On p. 23 of the handbook we read: "the terms absolute and relative measurements should be avoided, since no absolute, i.e. faultless measurements are possible." In our literature absolute measurements are understood to be indirect measurements which depend on direct measurements of length, mass, and time (see M. F. Malikov, "Foundations of Metrology", p. 37).

On p. 26 it is stated that the term "correction" should be used as little as possible, "in order to avoid confusion in signs", whereas in Soviet specification corrections are always given.

In the handbook angle gauges are called "angle end gauges" (p. 358); the term "wringing of block gauges" is replaced by "sticking" (p. 345). In the handbook block gauges are classed as "reference", "comparative", "testing", and "working" (p. 348) instead of our terminology of "reference gauges" and "working gauges."

On pages 349 and 350 various careless translations are made. (The Russian text then proceeds to quote certain terms in the Russian translation which do not agree with GOST 4119-49).

The above list of translation defects we have noticed is far from being complete.

Obviously, the handbook cannot provide exhaustive and detailed information on all the problems it deals with. In such cases the reader should be informed of the special literature dealing with the questions in which he may be interested, but unfortunately the handbook does not contain any references to numerous Soviet sources. This defect also, to a great extent, reduces the value of the book under review.

The many shortcomings and defects found in this handbook lead us to think that its publication in the present form without modifications, full of standards used in Germany and not in the USSR, and failing to mention the achievements of Soviet measurement technology, is hardly justified, since in many instances the handbook may only lead to confusion.

FEINWERK TECHNIK

1961, No. 2

W. Bachman. Mechanical measuring instruments with an elastic sensing element. Computation and design of pointer instruments.

E. Nickel. New design for liquid manometric scales.

1961, No. 3

W. Hoch. International congress and exhibition on measurement technology and automation "Interkama", held in Dusseldorf on October 19-26, 1960.

Descriptions, schematics, and photographs of instruments shown at the exhibition are provided, including those of: bridges and compensators, oscilloscopes, recording and digital measuring instruments, electronic weighing instruments, instruments using radioactive radiations, etc.

W. Bürk. Application of the principle of standardized units in designing electronic measuring instruments.

1961, No. 4

P. Nenning. Measurement errors due to friction in measuring instrument components.

INSTRUMENTS AND CONTROL SYSTEMS

1960, No. 11

Investigations of temperature measurements in the range of 90 to 20° K carried out by the National Bureau of Standards.

S. Williams. Triple point of water as a reference point in the temperature scale. Description of a special ampoule for the triple point of water which provides a reproducibility of 0.0001° C.

E. Kebbon. Various instruments and devices for measuring surface temperature. The principles of operation of pyrometric cones, temperature-sensitive pencils and paints as well as noise thermomenters are provided.

R. MacDonald. Utilization of infrared radiations for measuring gas temperatures. Review of existing methods and instruments which use infrared radiations and serve for measuring high temperatures, rapidly changing temperatures, remote measurements, measurements of moving object temperatures, etc.

N. House. Devices for automatic pressure compensation used in gas meters.

MESURES & CONTROLE INDUSTRIEL

1961, No. 285

G. Gontier. Optical methods of observation and measurements in gases (interferometer, shadow, striascopic). (End).

The article deals with optical interferometer measurements used in pyrodynamics, and with various types of interferometers, including those with divided light beams, with a diffraction grating, as well as differential interferometers.

G. Roy. Investigation of a portable psychrometer for precision measurements of humidity.

Various methods of measuring atmospheric humidity are examined, and the construction of a psychrometer with two thermometers, which is most suitable for the above purpose, is described.

1961, No. 286

M. Le Get. The theory of mirror galvanometers. Requirements of recording galvanometers (sensitivity, linearity, frequency characteristic). Critical resistance.

J. Roy and G. Gohar. Equipment and circuits based on fixed points which serve for calibrating thermocouples.

G. Entier. Recording device for McBain's thermal scales.

Report on the exhibition "Achema", 1961, in Frankfurt-on-Main, on chemical instrument-making.

VDI ZEITSCHRIFT

1961, No. 1

O. Teiss. Special manometer design with a diaphragm box.

1961, No. 3

K. Kreitzer. Obtaining temperatures which approach the absolute zero.

The article deals with special methods for magnetic cooling of paramagnetic salts and nuclear cooling in conjunction with the use of a helium cryostat which provided very low temperatures of the order of $1.5 \cdot 10^{-6°}$ K.

R. Karl. The importance of control and measurement techniques in engineering technology.

The use of control and measurement techniques for the correct setting of tools and precision machining of articles on a lathe. Checking the accuracy of finished articles.

I·S·A Journal

1961, No. 3

L. Hagey. The necessity of improving the system of technical measurements and the inspection service in the USA.

G. Lockery. Various methods of measuring torque by means of resistance strain gauges.

1960, v. 14, No. 6

R. Hall and others. Dynamic method for measuring distance by determining the speed and displacement time of the measured object.

1961, v. 15, No. 1

G. Hesing. Determining the surface finish of articles by comparing them with a reference model.

IN THE COMMITTEE OF STANDARDS, MEASURES AND MEASURING INSTRUMENTS

I. NEW SPECIFICATIONS FOR MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE

NEW STANDARDS

(Registered in January-April, 1961)

Translated from Izmeritel'naya Tekhnika, No. 6, p. 64, June, 1961

GOST (All-Union State Standard) 3044-61. Thermocouples. Calibration tables for cold junctions at 0° C. Replacing GOST 3044-45. Effective from January 1, 1962.

GOST 4046-61. Sine rules. Replacing GOST 4046-48. Effective from January 1, 1962.

GOST 6616-61. Thermocouples. Replacing GOST 6616-53. Effective from January 1, 1962.

GOST 7664-61. Mechanical units. Replacing 7664-55. Effective from July 1, 1961.

GOST 8042-61. Electrical measuring instruments. Interchangeable shunts. Replacing GOST 8042-56. Effective from July 1, 1961.

GOST 9694-61. Glass tubes for level ampoules. Effective from October 1, 1961.

GOST 9696-61. Multiturn dial indicators calibrated in 0.001 and 0.002 mm. Effective from January 1, 1962.

GOST 9736-61. Millivoltmeters and ratiometers for measuring nonelectrical quantities. Replacing GOST 6670-53 and GOST 6568-53. Effective from January 1, 1962.

II. MEASURES AND MEASURING INSTRUMENTS APPROVED BY THE COMMITTEE AS THE RESULT OF STATE TESTING, AND PASSED FOR USE IN THE USSR

(Registered in February-April, 1961)

Voltage transformers, trade mark NKF-330, Moscow city Sovnarkhoz (Council of National Economy). State Register No. 1443-61.

Ammeters and voltmeters, trade mark É381, Krasnodar Sovnarkhoz. State Register No. 1444-61.

Voltammeters, trade mark TT-3 and TL-4, Estonian Sovnarkhoz. State Register No. 1445-61.

Shockproof rack-mounted frequency meters, trade mark I166, Leningrad Sovnarkhoz. State Register No. 1446-61.

Nephelometers, trade mark NFM, Moscow city Sovnarkhoz. State Register No. 1447-61.

Micrometer hole gauges, trade mark NM 800-2500, Chelyabinsk Sovnarkhoz. State Register No. 1448-61.

Testing machines for textiles and rubber, trade mark RT-250, Moscow city Sovnarkhoz. State Register No. 1449-61.

Special vacuum manometers, state register MPV, Poltava Sovnarkhoz. State Register No. 1450-61.

Burettes with an automatic zero, Moscow regional Sovnarkhoz. State Register No. 1451-61.

Thermo-electric power comparators, trade mark T 119/1, Leningrad Sovnarkhoz. State Register No. 1325-61. Replacing previously registered thermal comparators T119 under number 1325-60.

Portable ammeters, trade mark D57, previously entered in the State Register under No. 962, supplemented by modifications of ammeters D57/9-11 with ranges of 250 and 500 ma, 50 and 100 ma, and 25 and 50 ma. Kiev Sovnarkhoz.

Laboratory thermometers, trade mark TL-4, modified B-IV No. 6, B-IV No. 7, and B-IV No. 8, with ranges of 200-250° C, 250-300° C, 300-350° C, respectively, Moscow regional Sovnarkhoz. State Register No. 303-61, combined with thermometers TL modifications B-IV No. 1, B-IV No. 2, B-IV No. 3, B-IV No. 4, and B-IV No. 5, previously entered in the State Register under No. 303.

Current transformers, trade mark I515, Kiev Sovnarkhoz. State Register No. 1452-61.

Three-phase two element wattmeters, trade mark D771 and D772, Krasnodar Sovnarkhoz, State Register No. 1453-61.

III. MEASURES AND MEASURING INSTRUMENTS EXCLUDED FROM THE STATE REGISTER

Inductance box, trade mark MI, State Register No. 473, due to its replacement by inductance box R546, State Register No. 1300-59.

Ammeters and voltmeters, trade mark ÉP-2, State Register Nos. 543 and 544.

Voltmeters, trade mark S-95, State Register No. 660.

Cable set KP. State Register No. 731.

Mobile platform scales, trade mark VSP-0.5, 1, 2, and 3 tons. State Register No. 755.

Amperevoltwattmeters, trade mark D501. State Register No. 776.

Thermal comparators T119. State Register No. 1325-60.

Soviet Journals Available in Cover-to-Cover Translation

ABBREVIATION	RUSSIAN TITLE	TITLE OF TRANSLATION	PUBLISHER	TRANSLATION BEGAN Vol.	Issue	Year
AÉ	Atomnaya énergiya	Soviet Journal of Atomic Energy	Consultants Bureau	1	1	1956
Akust. zh.	Akusticheskii zhurnal	Soviet Physics – Acoustics	American Institute of Physics	1	1	1955
	Antibiotiki	Antibiotics	Consultants Bureau	4	1	1959
Astr(on). zh(urn).	Astronomicheskii zhurnal	Soviet Astronomy–AJ	American Institute of Physics	34	1	1957
Avto(mat). svarka	Avtomaticheskaya svarka	Automatic Welding	British Welding Research Association (London)		1	1959
	Avtomatika i Telemekhanika	Automation and Remote Control	Instrument Society of America	27	1	1956
	Biofizika	Biophysics	National Institutes of Health*		1	1957
	Biokhimiya	Biochemistry	Consultants Bureau	21	1	1956
Byull. éksp(erim). biol. i med.	Byulleten' éksperimental'noi biologii i meditsiny	Bulletin of Experimental Biology and Medicine	Consultants Bureau	41	1	1959
DAN (SSSR) / Dokl(ady) AN SSSR	Doklady Akademii Nauk SSSR	The translation of this journal is published in sections, as follows:				
		Doklady Biochemistry Section	American Institute of Biological Sciences	106	1	1956
		Doklady Biological Sciences Sections (Includes: Anatomy, biophysics, cytology, ecology, embryology, endocrinology, evolutionary morphology, genetics, histology, hydrobiology microbiology, morphology, parasitology, physiology, zoology sections)	American Institute of Biological Sciences	112	1	1957
		Doklady Botanical Sciences Sections (Includes: Botany, phytopathology, plant anatomy, plant ecology, plant embryology, plant physiology, plant morphology sections)	American Institute of Biological Sciences	112	1	1957
		Proceedings of the Academy of Sciences of the USSR, Section: Chemical Technology	Consultants Bureau	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Section: Chemistry	Consultants Bureau	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Section: Physical Chemistry	Consultants Bureau	112	1	1957
		Doklady Earth Sciences Sections (Includes: Geochemistry, geology, geophysics, hydrogeology, mineralogy, paleontology, petrography, permafrost sections)	American Geological Institute	124	1	1959
		Proceedings of the Academy of Sciences of the USSR, Section: Geochemistry	Consultants Bureau	106-123	1-6	1957-1958
		Proceedings of the Academy of Sciences of the USSR, Sections: Geology	Consultants Bureau	106-123	1-6	1957-1958
		Doklady Soviet Mathematics	The American Mathematics Society	131	1	1961
		Soviet Physics–Doklady (Includes: Aerodynamics, astronomy, crystallography, cybernetics and control theory, electrical engineering, energetics, fluid mechanics, heat engineering, hydraulics, mathematical physics, mechanics, physics, technical physics, theory of elasticity sections)	American Institute of Physics	106	1	1956
		Proceedings of the Academy of Sciences of the USSR, Applied Physics Sections (does not include mathematical physics or physics sections)	Consultants Bureau	106-117	1	1956-1957
Derevoobrabat. prom-st'.	Derevoobrabatyvayushchaya promyshlennost'	Wood Processing Industry	Timber Development Association (London)		9	1959
	Élecktrosvyaz	Telecommunications	Massachusetts Institute of Technology*		1	1957
Éntom(ol). oboz(renie)	Éntomologicheskoe obozrenie	Entomological Review	American Institute of Biological Sciences	38	1	1959
Farmakol. (i) toksikol(ogiya)	Farmakologiya i toksikologiya	Pharmacology and Toxicology	Consultants Bureau	20	1	1957
FMM	Fizika metallov i metallovedenie	Physics of Metals and Metallography	Acta Metallurgica*	5	1	1957
Fiziol. zhurn. SSSR (im. Sechenova)	Fiziologicheskii zhurnal im. I. M. Sechenova	Sechenov Physiological Journal USSR	National Institutes of Health*		1	1957
Fiziol(ogiya) rast.	Fiziologiya rastenii	Plant Physiology	American Institute of Biological Sciences	4	1	1957
	Geokhimiya	Geochemistry	The Geochemical Society		1	1958
FTT	Fizika tverdogo tela	Soviet Physics–Solid State	American Institute of Physics	1	1	1959
Izmerit. tekh(nika)	Izmeritel'naya tekhnika	Measurement Techniques	Instrument Society of America		1	1959
Izv. AN SSSR, O(td). Kh(im). N(auk)	Izvestiya Akademii Nauk SSSR: Otdelenie khimicheskikh nauk	Bulletin of the Academy of Sciences of the USSR: Division of Chemical Sciences	Consultants Bureau		1	1952

continued

Izv. AN SSSR, O(td). T(ekhn). N(auk): Met(all). i top.	(see Met. i top.)				
Izv. AN SSSR Ser. fiz(ich).	Izvestiya Akademii Nauk SSSR: Seriya fizicheskaya	Bulletin of the Academy of Sciences of the USSR: Physical Series	Columbia Technical Translations	1	1954
Izv. AN SSSR Ser. geofiz.	Izvestiya Akademii Nauk SSSR: Seriya geofizicheskaya	Bulletin (Izvestiya) of the Academy of Sciences USSR: Geophysics Series	American Geophysical Union	1	1954
Izv. AN SSSR Ser. geol.	Izvestiya Akademii Nauk SSSR: Seriya geologicheskaya	Izvestiya of the Academy of Sciences of the USSR: Geologic Series	American Geological Institute	1	1958
Kauch. i rez.	Kauchuk i rezina	Soviet Rubber Technology	Research Association of British Rubber Manufacturers	18	1 1959
	Kinetika i kataliz	Kinetics and Catalysis	Consultants Bureau	1	3 1960
	Koks i khimiya	Coke and Chemistry USSR	Coal Tar Research Association (Leeds, England)		1 1958
Kolloidn. zh(urn).	Kolloidnyi zhurnal	Colloid Journal	Consultants Bureau	14	1 1952
	Kristallografiya	Soviet Physics – Crystallography	American Institute of Physics	2	1 1957
Metalov. i term. obrabot. metal.	Metallovedenie i termicheskaya obrabotka metallov	Metal Science and Heat Treatment of Metals	Acta Metallurgica	6	1 1958
	Metallurg	Metallurgist	Acta Metallurgica		1 1957
Met. i top.	Metallurgiya i topliva	Russian Metallurgy and Fuels	Eagle Technical Publications		1 1960
Mikrobiol.	Mikrobiologiya	Microbiology	American Institute of Biological Sciences	26	1 1957
OS	Optika i spektroskopiya	Optics and Spectroscopy	American Institute of Physics		6 1959
	Pochvovedenie	Soviet Soil Science	American Institute of Biological Sciences		1 1958
	Priborostroenie	Instrument Construction	British Scientific Instrument Research Association		1 1959
Pribory i tekhn. éks(perimenta)	Pribory i tekhnika éksperimenta	Instruments and Experimental Techniques	Instrument Society of America		1 1957
Prikl. matem. i mekh.	Prikladnaya matematika i mekhanika	Applied Mathematics and Mechanics	American Society of Mechanical Engineers		1 1958
PTÉ	(see Pribory i tekhn. éks.)				
	Problemy Severa	Problems of the North	National Research Council of Canada		
Radiotekh.	Radiotekhnika	Radio Engineering	Massachusetts Institute of Technology*	12	1 1957
Radiotekh. i élektronika	Radiotekhnika i élektronika	Radio Engineering and Electronics	Massachusetts Institute of Technology*	2	1 1957
	Stanki i instrument	Machines and Tooling	Production Engineering Research Assoc.		1 1959
	Stal'	Stal (In English)	Iron and Steel Institute		1 1959
Stek. i keram.	Steklo i keramika	Glass and Ceramics	Consultants Bureau	13	1 1956
Svaroch. proiz-vo	Svarochnoe proizvodstvo	Welding Production	British Welding Research Association		4 1959
Teor. veroyat. i prim.	Teoriya veroyatnostei i ee primenenie	Theory of Probability and Its Applications	Society for Industrial and Applied Mathematics		1 1956
Tsvet. Metally	Tsvetnye metally	Nonferrous Metals	Primary Sources		1 1960
UFN	Uspekhi fizicheskikh Nauk	Soviet Physics – Uspekhi (partial translation)	American Institute of Physics	66	1 1958
UKh	Uspekhi khimii	Russian Chemical Reviews	The Chemical Society (London)		1 1960
UMN	Uspekhi matematicheskikh nauk	Russian Mathematical Surveys	London Mathematical Society	15	1 1960
Usp. fiz. nauk	(see UFN)				
Usp. khim(ii)	(see UKh)				
Usp. matem. nauk	(see UMN)				
Usp. sovr. biol.	Uspekhi sovremennoi biologii	Russian Review of Biology	Oliver and Boyd	48	1959
Vest. mashinostroeniya	Vestnik mashinostroeniya	Russian Engineering Journal	Production Engineering Research Assoc.	4	1959
Vop. gem. i per. krovi	Voprosy gematologii i perelivaniya krovi	Problems of Hematology and Blood Transfusion	National Institutes of Health*	1	1957
Vop. onk.	Voprosy onkologii	Problems of Oncology	National Institutes of Health*	1	1957
Vop. virusol.	Voprosy virusologii	Problems of Virology	National Institutes of Health*	1	1957
Zav(odsk). lab(oratoriya)	Zavodskaya laboratoriya	Industrial Laboratory	Instrument Society of America	25	1 1959
ZhAKh Zh. anal(it). khimii	Zhurnal analiticheskoi khimii	Journal of Analytical Chemistry USSR	Consultants Bureau	7	1 1952
ZhETF Zh. éksperim. i teor. fiz.	Zhurnal éksperimental'noi i theoreticheskoi fiziki	Soviet Physics–JETP	American Institute of Physics	28	1 1955
ZhFKh Zh. fiz. khimii	Zhurnal fizicheskoi khimii	Russian Journal of Physical Chemistry	The Chemical Society (London)		7 1959
ZhMÉI Zh(urn). mikrobiol. épidemiol. i immunobiol.	Zhurnal mikrobiologii, épidemiologii i immunobiologii	Journal of Microbiology, Epidemiology and Immunobiology	National Institutes of Health*		1 1957
ZhNKh Zh(urn). neorgan(ich). khim(ii)	Zhurnal neorganicheskoi khimii	The Russian Journal of Inorganic Chemistry	The Chemical Society (London)		1 1959
ZhOKh Zh(urn). obshch(ei) khimii	Zhurnal obshchei khimii	Journal of General Chemistry USSR	Consultants Bureau	19	1 1949
ZhPKh Zh(urn). prikl. khimii	Zhurnal prikladnoi khimii	Journal of Applied Chemistry USSR	Consultants Bureau	23	1 1950
ZhSKh Zh(urn). strukt. khimii	Zhurnal strukturnoi khimii	Journal of Structural Chemistry	Consultants Bureau	1	1 1960
ZhTF Zh(urn). tekhn. fiz.	Zhurnal teknicheskoi fiziki	Soviet Physics–Technical Physics	American Institute of Physics	26	1 1956
Zh(urn). vysshi. nervn. deyat. (im. Pavlova)	Zhurnal vysshei nervnoi deyatel'nosti (im. I. P. Pavlova)	Pavlov Journal of Higher Nervous Activity	National Institutes of Health*		1 1958

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

*Sponsoring organization. Translation through 1960 issues is a publication of Pergamon Press.

SIGNIFICANCE OF ABBREVIATIONS MOST FREQUENTLY ENCOUNTERED IN SOVIET TECHNICAL PERIODICALS

AN SSSR	*Academy of Sciences, USSR*
FIAN	*Physics Institute, Academy of Sciences USSR*
GITI	*State Scientific and Technical Press*
GITTL	*State Press for Technical and Theoretical Literature*
GOI	*State Optical Institute*
GONTI	*State United Scientific and Technical Press*
Gosénergoizdat	*State Power Press*
Gosfizkhimizdat	*State Physical Chemistry Press*
Goskhimizdat	*State Chemistry Press*
GOST	*All-Union State Standard*
Gostekhizdat	*State Technical Press*
GTTI	*State Technical and Theoretical Press*
IAT	*Institute of Automation and Remote Control*
IF KhI	*Institute of Physical Chemistry Research*
IFP	*Institute of Physical Problems*
IL	*Foreign Literature Press*
IPF	*Institute of Applied Physics*
IPM	*Institute of Applied Mathematics*
IREA	*Institute of Chemical Reagents*
ISN (Izd. Sov. Nauk)	*Soviet Science Press*
IYap	*Institute of Nuclear Studies*
Izd	*Press (publishing house)*
LÉTI	*Leningrad Electrotechnical Institute*
LFTI	*Leningrad Institute of Physics and Technology*
LIM	*Leningrad Institute of Metals*
LITMiO	*Leningrad Institute of Precision Instruments and Optics*
Mashgiz	*State Scientific-Technical Press for Machine Construction Literature*
MGU	*Moscow State University*
Metallurgizdat	*Metallurgy Press*
MOPI	*Moscow Regional Pedagogical Institute*
NIAFIZ	*Scientific Research Association for Physics*
NIFI	*Scientific Research Institute of Physics*
NIIMM	*Scientific Research Institute of Mathematics and Mechanics*
NIKFI	*Scientific Institute of Motion Picture Photography*
NKTM	*People's Commissariat of the Heavy Machinery Industry*
Obrongiz	*State Press of the Defense Industry*
OIYaI	*Joint Institute of Nuclear Studies*
ONTI	*United Scientific and Technical Press*
OTI	*Division of Technical Information*
OTN	*Division of Technical Science*
RIAN	*Radium Institute, Academy of Sciences of the USSR*
SPB	*All-Union Special Planning Office*
Stroiizdat	*Construction Press*
URALFTI	*Ural Institute of Physics and Technology*
TsNIITMASh	*Central Scientific-Research Institute of Technology and Machinery*
VNIIM	*All-Union Scientific Research Institute of Metrology*

NOTE: Abbreviations not on this list and not explained in the translation have been transliterated, no further information about their significance being available to us — *Publisher.*

Publication of a "Soviet Instrumentation and Control Translation Series" by the Instrument Society of America has been made possible by a grant in aid from the National Science Foundation, with additional assistance from the National Bureau of Standards for the journal *Measurement Techniques.*

Subscription rates have been set at modest levels to permit widest possible distribution of these translated journals.

The Series now includes four important Soviet instrumentation and control journals. The journals included in the Series, and the subscription rates for the translations, are as follows:

MEASUREMENT TECHNIQUES – *Izmeritel'naya Tekhnika*

Russian original published by the Committee of Standards, Measures, and Measuring Instruments of the Council of Ministers, USSR. The articles in this journal are of interest to all who are engaged in the study and application of fundamental measurements. Both 1958 (bimonthly) and 1959-1961 (monthlies) available.

Per year (12 issues) starting with 1961, No. 1

General:	United States and Canada . .	$25.00
	Elsewhere	28.00
Libraries of nonprofit academic institutions:		
	United States and Canada . .	$12.50
	Elsewhere	15.50

INSTRUMENTS AND EXPERIMENTAL TECHNIQUES
Pribory i Tekhnika Éksperimenta

Russian original published by the Academy of Sciences, USSR. The articles in this journal relate to the function, construction, application, and operation of instruments in various fields of experimentation. 1958-1961 issues available.

Per year (6 issues) starting with 1961, No. 1

General:	United States and Canada . .	$25.00
	Elsewhere	28.00
Libraries of nonprofit academic institutions:		
	United States and Canada . .	$12.50
	Elsewhere	15.50

AUTOMATION AND REMOTE CONTROL – *Avtomatika i Telemekhanika*

Russian original published by the Institute of Automation and Remote Control of the Academy of Sciences, USSR. The articles are concerned with analysis of all phases of automatic control theory and techniques. 1957-1961 1959, and 1960

Per year (12 issues) starting with Vol. 22, No. 1

General:	United States and Canada . .	$35.00
	Elsewhere	38.00
Libraries of nonprofit academic institutions:		
	United States and Canada . .	$17.50
	Elsewhere	20.50

INDUSTRIAL LABORATORY – *Zavodskaya Laboratoriya*

Russian original published by the Ministry of Light Metals, USSR. The articles in this journal relate to instrumentation for analytical chemistry and to physical and mechanical methods of materials research and testing. 1958-1961 issues available.

Per year (12 issues) starting with Vol. 27, No. 1

General:	United States and Canada . .	$35.00
	Elsewhere	38.00
Libraries of nonprofit academic institutions:		
	United States and Canada . .	$17.50
	Elsewhere	20.50

Single issues of all four journals, to everyone, each . . . $6.00

Prices on 1957-1960 issues available upon request

SPECIAL SUBSCRIPTION OFFER:

One year's subscription to all four journals of the 1961 Series, as above listed:

General:	United States and Canada . .	$110.00
	Elsewhere	122.00
Libraries of nonprofit academic institutions:		
	United States and Canada . .	$ 55.00
	Elsewhere	67.00

Subscriptions should be addressed to:

Instrument Society of America
530 William Penn Place
Pittsburgh 19, Penna.

124